MILITARY WORKS HANDBOOK.

[THIRD EDITION.]

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PREFACE.

The reprint of the Second Edition of this Book being exhausted a new Edition has been prepared.

The Tables, Formulæ, and Specifications have been carefully revised, and a good deal of new matter, particularly with reference to Water-supply, has been added; the Book now forms a complete compendium of information on all kinds of work ordinarily carried out by the Military Works Services.

The work is based on the Handbook drawn up by Mr. Tyndall for the Executive Engineers of the old 3rd Circle of the Military Works, and is not intended to supersede standard works on the subjects dealt with, but merely as a Handbook for use generally in the preparation of estimates.

S. C. TURNER, Major-General,
Director-General, Military Works.

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PART I.

SPECIFICATIONS.

SPECIFICATIONS.

These Specifications are general ones for guidance in the execution of work throughout the Department; they are not intended to supersede Divisional Specifications where such exist duly approved by proper Authority.

Earthwork.

I. Excavation. *Excavation for Foundations, Earthwork, &c.*—

1. The excavation for foundations is to be in exact accordance with the plans, sections, &c., furnished, and care must be taken that the bottoms of the trenches are perfectly level, both longitudinally and transversely, and that the steppings, where indicated on the plans, are strictly attended to.

2. If the excavation is in earth, the bottoms of the foundation trenches are to be well watered and rammed, care being taken that too much water is not used, or soft mud may be formed; and if such ramming brings to light any soft or defective places, a report is at once to be made to the Executive Engineer, and the holes should then be filled in with concrete, or be treated in such a way as the Executive Engineer may direct.

3. When rock has to be excavated, the lower surface of the trenches must be made as level and true as possible in accordance with the plans, and the Executive Engineer's directions must be taken as to the filling in with concrete of any small inequalities which it might be difficult or expensive to level.

4. No material excavated from foundation trenches, of whatever kind it may be, is to be placed nearer than one foot to the outer edges of the excavation.

5. As soon as the foundation trenches are completely excavated in exact accordance with the drawings, (or as directed by the Executive Engineer,) and made ready in other respects as above described, a report is to be made to the Executive Engineer to this effect, in order that he may make a final inspection of the work, and that he may give orders for

the commencement of the building of the foundations. Without such inspection, accompanied by the Executive Engineer's written permission given to the Contractor or Overseer in charge, the building is not to be commenced on any account.

6. II. **Earth filling, &c.**—As soon as the building is finished to the top of the plinth level, the space between the foundations and the side of the foundation trenches is to be cleared of whatever *débris* may have fallen therein, and is to be then filled in with earth laid in 9-inch courses, well watered and rammed.

7. As soon as the superstructure of the main walls is 2 feet high above the plinth level, the plinth may be filled in with earth in 9-inch courses, well watered and rammed; and a sufficient depth of this earth may afterwards be removed where required, so as to make room for the specified flooring.

8. On completion of the building, the ground all round to a distance of 50 feet is to be carefully dressed and given a gentle slope outwards of 1 in 40.

Mortar.

1. **Lime.**—Limestone or kankar must be burned with coal, charcoal or wood, and not with *úpla* (cowdung cakes). A design for a kiln is given in *Plate* XVIII.

2. Lime must be delivered at the site of the mortar mill quite fresh, *i.e.*, within seven days of the date on which it was burned; it must be entirely free from ashes, under-burned particles, and other impurities.

3. Lime may be either slaked, or ground fine in properly made mills as shown in *Plate* XIX., according to the custom in the district in which the manufacture is being prosecuted, or as may be directed by the Executive Engineer; but it must always have been passed through a sieve of 64 meshes to the inch, before it is put in the trough for mixing.

4. Súrkhí must always be made of thoroughly well burned bricks, by grinding or pounding the latter. It must be perfectly clean, free from any admixture of foreign matter, and it must have been passed through a screen of 64 meshes to the inch, before being mixed with the lime.

5. **Sand or Budjri.**—Sand must be sharp, clean, river sand, free from all admixture of earth or other impurities, to effect which, it must be washed when necessary. In a similar way as in the case of súrkhi,

it must have been passed through a sieve of 64 meshes to the inch, before being mixed for mortar.

6. **Mixing.**—Mortar will be composed of lime and súrkhí or sand in various proportions according to the nature of the lime used, to be fixed by experiment at each station, and approved by the Superintending Engineer. The specified proportion of lime is always to be in lime powder, either hot ground or slaked lime and not in lump. (On pages 7 and 8 the proportions used at various stations of the Meerut Circle are given).

7. All mortar will be mixed by measure, not by the weight of the ingredients, which will be ground in the mill as before described, until they are thoroughly incorporated, care being taken that too much water is not used in the operation. The grinding must continue for four hours at least before the mortar can be considered fit for use.

8. Mortar which has once set, or which has lain for more than 24 hours after it has been ground, must on no account be used in any work. When using kankar lime for plastering it is however better to leave it for some time to sour.

9. Mortar should be kept ready for use in the narrow troughs shown in *Plate* XIX., and in hot weather it should be covered with matting or thatch to prevent its drying or setting too quickly from excessive heat.

Concrete.

1. **Ingredients.**—Concrete is to be composed of the ingredients found by experiment at each station to be most suitable, and approved by the Superintending Engineer. (On pages 7 and 8 the proportions used at various stations in the Meerut Circle are given). Its position and dimensions should be those shown on the plans, unless other directions shall be specially given by the Superintending or Executive Engineer.

2. **Mortar.**—The mortar for concrete will be prepared as described above. It must then be thoroughly incorporated with the broken brick, broken stone, or gravel, (as the case may be,) or prepared as may be specially directed.

3. **Ballast.**—The broken stone, broken brick, or gravel, must be perfectly clean and free from all impurities before being mixed with the mortar, and must have been soaked in water for at least four hours previous to mixing.

4. For the mixing of the concrete, a special broad shallow platform

must be built. This platform should be floored with brick or flagging, so as to keep the materials clean and pure.

5. Broken brick must be thoroughly well burned, and no individual piece, either of this material, of gravel, or of broken stone, which is intended for use in concrete, should exceed in size what will pass, in any direction, through a ring $1\frac{1}{2}$ inches in diameter. Smaller pieces may be used, however, with advantage, down to those which will pass through a ring half an inch in diameter.

6. **Laying.**—The concrete must always be used while quite fresh. It must be *laid* (not *thrown*) in the trenches, or in any position in which it may be desired to place it.

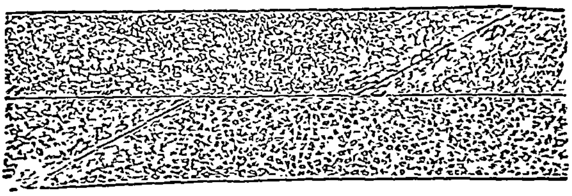
7. Concrete should be laid in courses, each course being as nearly 6 inches in thickness, as the convenience of construction will allow. Each course is to be well rammed and consolidated before the next is laid.

8. No concrete is to be laid after 2 p.m., this is to ensure its being properly consolidated before night-fall and prevent the necessity for further ramming next day after the mortar has had time to set.

9. Concrete must not be laid in too fluid a consistency, after it has been mixed no more water should be added, the surface during and after consolidation must however be kept damp for at least seven days.

10. Iron rammers, not weighing less than 12 lbs., should be used, and the ramming should continue until the lime has partially set, or until a walking stick, when dropped endways upon it from a height, will rebound from the surface: with brick ballast wooden rammers may be used.

11. In laying consecutive layers of concrete, the lower course should be well watered before the upper is laid; and, where it is necessary to make joints in layers, they should be arranged as shown in the margin.



12. **Portland Cement Concrete.***—The concrete should be mixed in the following proportions, *viz.*:—

Broken stone, small, 3 parts; clean sharp river sand, 2 parts; cement, 1 part. In large walls or heavy foundations 30 cubic feet of large stones may be added to 100 cubic feet of the cement concrete, mixed as above, before laying.

* For further particulars regarding Portland cement concrete in subaqueous work, *see* D. G. M. W. Circular No. 7B of 9th May, 1893.

13. The cement used must be of a well known brand, and it must be passed through the finest sieve locally procurable before mixing it with the other ingredients. Care must be taken that the cement be not too fresh; in this case it should be laid out on a floor for a few days under cover, in order to get rid of any heat, which would cause it to blow or swell in setting. If exposed thus in dry weather for some time, up to three weeks, it increases in both strength and bulk.

14. Cement concrete will be mixed and laid as specified above, but the following additional precautions must be taken :—

The ballast after having been well soaked should be allowed to dry externally and be mixed first with dry sand and cement. Water should not be added until just before it is intended to lay the concrete; it should be poured on gently through the rose of a watering pot, care being taken that the mass is not allowed to become too fluid in consistency. It should be laid as soon as mixed, and all ramming necessary must be done on the same day it is laid. On the following day it should be covered with water and kept so for 14 days. In places where this cannot be done wet sand is to be used instead of water.

Table of Dry Ingredients of Mortar,

Used at different Stations in the Meerut Circle—Mortar 1·00 *cubic feet.*

Division.	Station.	Lime.	Sùrkhí.	Budjri or sand.	Remarks.
		c. feet.	c. feet.	c. feet.	
Agra,	Agra, ...	55	...	82·5	Kankar lime.
Bareilly,	Bareilly, ...	62·5	...	62·5	,, ,,
	Shahjahanpur,	125	...	...	,, ,,
	Naini Tal, ...	62·5	...	62·5	Stone lime.
	Ranikhet, ...	50	75	...	[illegible]
	Almora, ...	50	75	...	[illegible]
	Lansdowne, ...	42	42	42	
Chakrata,	Chakrata, ...	41·67	...	83·33	
	Dehra, ...	50	...	75	
	Landour, ...	50	...	75	
	Roorkee, ...	50	75	[illegible]	
	Saharanpur, ...	50	75		
Jhansi,	Jhansi, ...	64	...	[illegible]	[illegible]
	Nowgong, ...	56	...	[illegible]	
Meerut,	Meerut, ...	[illegible]	...	[illegible]	
	Babugarh, ...	[illegible]		[illegible]	
	Delhi, ...	[illegible]		[illegible]	
	Muttra, ...	[illegible]		[illegible]	

Proportions of Mortar and Ballast for Concrete.

	Mortar.	Ballast.
For layers of 6″ in thickness and over, ...	30	100
" " of less than 6″ in thickness, ...	35	100
" terraced floors and roofs, ...	50	100

Brickwork.

1. **Description of Brickwork.**—First class brickwork will consist of stock-made bricks of uniform colour and shape, thoroughly well burned, and of a deep red or copper colour. Each brick must be square and well shaped, must ring clearly when struck, and must be perfectly sound in all respects.

2. Second class brickwork will consist of bricks which are thoroughly burned, sound, and well shaped. They will be the same as first class bricks, with the exception that the colour need not be quite so high, or uniform throughout the structure. The inner bricks may be of a lighter colour, but for all face work, bricks should be selected for uniformity of colour.

3. There will be no difference whatever between first and second class brickwork, either in the mortar used, in the method of laying, or in the bond.

4. First and second class brickwork will be built as indicated on the plans, as specified by the Executive Engineer in his estimate, or as directed by that officer on the works; and at the rates agreed to in the contract bond.

5. **Bond, &c.**—The bond to be used in all brickwork will be "English," *see Plates* X. and XI., and no half-bricks or brick-bats will be allowed to be used, except when necessary to complete the bond.

6. In building arches, concentric rings are not to be used, but each course of the arch must be regularly and systematically bonded, *see Plate* XII.

7. All bricks in each course of an arch must be regularly and carefully summered to the radius of the arch; and this, when practicable should be effected by moulding and burning the bricks specially for the work; in cases where the amount of arch work to be done is small, the summering may be effected by cutting or grinding.

8. **Mortar.**—The mortar to be used will be as specified on pages 4 and 5.

9. **Laying.**—Care must be taken that each course of bricks laid is quite level and perfect in bond, and that each brick is well bedded and flushed in sound mortar.

10. No joints or beds are to exceed three-eighths of an inch in thickness, and those in arches should not exceed one-quarter of an inch. The mortar used in arches must be ground very fine, and made into what is known as "lime putty." This operation will be performed in small hand or country flour mills.

11. In the face of a wall, every five bricks must cover 3 feet $10\frac{1}{2}$ inches in length, when the bricks measure $9'' \times 4\frac{1}{2}'' \times 2\frac{3}{4}''$; and no four courses, including three joints, shall gauge in height more than 1 inch in addition to the thickness of the bricks themselves.

12. Walls are always to be carried up as level as possible along their entire length, and no step, left temporarily during construction, is ever to exceed eight courses in depth.

13. When brickwork in one section of a building cannot be carried up in level courses, the work must be raked back in regular steps (one course each) so that the new work to be added may be built on over the old.

14. Care must be taken to ensure all iron or stone fixtures, perforated jamb bricks, &c., being built into the work as it proceeds, in the position shown in the drawings, or as directed by the Executive Engineer.

15. The space between a relieving arch and a flat arch or lintel should not be filled in until the building is completed, unless it is found to be absolutely necessary to do so.

16. **Scaffolding.**—Scaffolding must be double, *i.e.*, it must have two sets of upright supporters. Care must be taken in leaving out a brick to allow the end of the scaffolding pole on the inner side to rest on the wall, that such brick is always a header, and that more than one header for each pole is never left out. By this means the bond of the wall can easily be made complete and perfect as the scaffolding is being removed.

17. **Watering.**—Care must be taken that walls, as they progress, are kept thoroughly well watered on their faces and tops; and, when work is left off at night, a fillet of mortar about $1\frac{1}{2}$ inches high should be made round the edge of the last course laid, so as to form a trough, which should be filled with water before the workmen leave off work for the day.

18. No brick is to be used unless it has been thoroughly soaked in water for at least two hours.

19. Garden-shaped watering pots should be used for wetting brick-work, the upper half only of the rose being perforated.

20. Where new and old brickwork are to be connected together, the old work must be well wetted and saturated with water for two days previously to the new work being commenced.

21. All new work when built must be kept watered and damp for at least five days.

22. **Brickwork in clay.**—Walls will be built of bricks laid in clay when ordered or specified. This work will be as specified for brickwork in mortar with the following exceptions :—

(*a*). The cementing material will be well tempered clay instead of mortar.

(*b*). The top courses of unfinished work need not be kept covered with water.

23. The mud mortar is to be made of stiff white or red clay according to locality, which is to be broken up into a fine powder and freed from stones, grass, or other impurities. It is first mixed with water on a brick or wooden platform and well worked up with the feet to the consistency of clay for brick-making. It is then to be gradually thinned with water until it assumes the consistency of stiff mortar when it will be ready for use.

24. **Sun-dried Bricks in clay mortar.**—Walls will be built of sun-dried bricks in clay mortar when ordered or specified. They will usually consist of unburnt stock bricks laid as specified for burnt brickwork in clay.

Stone Masonry.

1. **General.**—The masonry to be used will be *Ashlar work, Coursed rubble, Random squared coursed rubble, Random coursed rubble, Random uncoursed rubble, or Dry rubble* as may be specified.

2. The different kinds of masonry will be built in the positions indicated on the plans, and described by the Executive Engineer in his specification as herein laid down, or, as may be ordered on the spot, at the rates agreed to in the contract bonds.

3. The stone to be used will be that taken from the quarries mentioned by the Executive Engineer in his specification, or as may be directed.

It will be hard, durable, and tough, and each stone must be laid when in the work, on its natural quarry bed; all stones will be soaked in water for at least four hours before being put into the work.

4. The mortar to be used will be as specified for brickwork.

5. All masonry should be kept well watered in the same manner as is laid down for brickwork, until seven days after its completion shall have elapsed.

6. Scaffolding will be double, as described under that head for brickwork, but the ends of poles need not in this instance be placed in the position of a header stone.

7. **Ashlar work.**—Generally speaking, for all ashlar work, the Executive Engineer will supply the Contractor with the exact dimensions of each stone, or with a plan of each course of masonry showing the necessary dimensions.

8. Ashlar work will have its beds and joints finely dressed, free from any winding, and true and square in every respect.

9. All joints and beds will be perfectly vertical and horizontal respectively; they will never exceed $\frac{1}{4}$-inch in width or depth, and each stone will be well set and flushed up in mortar, as laid down under that head on pages 4 and 5.

10. All joints and beds of ashlar work will be constructed, as laid down in para. 9, but the outer face or faces may be *rock-faced, finely chisel-dressed, rock-faced with chisel margin, rock-faced with chisel margin and chamfered edge, sparrow picked with chisel margin*, or as may be described by the Executive Engineer, either in his specification, or on the ground.

11. Ashlar work shall never be laid in courses of less than 10 inches in height; no stone should be of less volume than $1\frac{1}{4}$ cubic feet, one-fifth of the face should be headers, and no stone should have a less width of bed than $1\frac{1}{2}$ times its height.

12. When ashlar quoins or ring stones are provided, the arrises must be dressed clean, sharp, true, and free from all winding; in the former quite plumb and vertical, and in the latter lying exactly in the line of the perimeter of the circle indicated or directed.

13. **Coursed rubble.**—Coursed rubble will be laid in courses varying in height as may be most convenient and economical, according to the nature of the stone procured from the quarry, as regards either the depth of the natural beds of the stone, or the manner in which it will

cleave, but no course will ever be less than $4\frac{1}{2}$ inches, or more than 9 inches in thickness.

14. Coursed rubble may have its courses either of equal or of unequal height; but in the latter instance, the deeper courses must be laid towards the bottom of the structure, and may gradually get shallower within the limit given above, as the wall progresses in height.

15. All buildings constructed with coursed rubble masonry should be supplied with ashlar quoins of the height of one or two courses, and care should be taken, when equal courses are specified, that the height of the wall is divided into an exact number of courses, and an exact number of quoins.

16. Equally or unequally coursed rubble masonry will be built as laid down in the Executive Engineer's specification, or as may be otherwise directed, at the rates agreed to in the contract bond.

17. All beds and joints must be perfectly true, both horizontally and vertically throughout. They must never be more than half an inch in width or depth, respectively; the line of each course must be perfectly level and free from winding; and no joint must overlie another less than $4\frac{1}{2}$ inches, measured on the face of the wall.

18. No stone should be used which is less than half a cubic foot in size, its bed must never be less than $1\frac{1}{2}$ times its height.

19. One-fifth of the face of the wall should be headers, and in walls up to 3 feet thick, all headers should be through-stones. All other stones shall be in half bond, or should overlap each other never less than one-third of the width of the wall.

20. Every stone must be carefully and truly laid, and will be flushed up in mortar as laid down under that head on pages 4 and 5.

21. **Random square coursed rubble.**—This description of masonry will be coursed every 18 inches in height, and will have quoins of equal or unequal height, but every two quoins must equal the height of a single course. *See Plate* XIV.

22. Each course will be made up of unequally sized stones, dressed perfectly square and true to whatever size is possible from its dimension, as it comes from the quarry.

23. Two stones may have their joints immediately over another, but the third stone should always overlap at least $3\frac{1}{2}$ inches. One-fifth of the face of the wall should consist of through headers. All other stones should be in half bond, or should overlap each other at least one-third the width of the wall.

24. All joints and beds must be perfectly vertical and horizontal respectively, and must never exceed half an inch in width or thickness throughout.

25. No stone must be laid whose bed is not at least $1\frac{1}{2}$ times its height, and the work may be roughly punched, each stone being well flushed in mortar as specified on pages 4 and 5.

26. **Random coursed rubble.**—For this description of masonry *see Plate* XIV. Each stone will be punched in to the number of sides to which it can be most conveniently dressed, and will be then so fitted into the wall, that the joints shall never exceed half an inch throughout. The vertical joints of each course must break joint at least 3 inches with those of the courses above and below it, and no face stone is on any account to be narrower or shorter than its height. If it be of irregular shape its length at right angles to the face of the wall must be at least $1\frac{1}{2}$ times its height.

27. Random coursed rubble masonry should be supplied with equal or unequal quoins, and should be coursed every 18 inches, one-fifth of the face should be through headers, and no stone should be less in depth than $1\frac{1}{2}$ times its height, every stone being well flushed in mortar as described for masonry under other heads.

28. All stones which are not headers shall half bond or overlap with one another, at least one-third the width of the wall, and the quoins may be either of equal or of unequal height; but there must always be two quoins to every 18 inches of wall in height.

29. **Random uncoursed rubble.**—The stones will be laid at random without being brought up to any level courses, each stone will be laid on its quarry bed, will be bedded in an ample supply of mortar, and will be wedged or pinned strongly into its position in the wall by spalls or chippings, which may show on the face.

30. No fixed rule can be laid down for sizes of joints, but they must be kept as small as possible. This work is subject to the same rules for through or bond stones, as specified above for other classes of rubble masonry.

31. River boulders and large pebbles may be used for this sort of work, either laid in their natural forms, or split, and their fractured surfaces shown on the face of the work.

32. When walls are built of this material, bands of brickwork, or masonry of a more regular description, should at fixed vertical intervals,

run through the whole thickness of the wall, to assist in tying it all together.

33. **Masonry in clay.**—When any of the above kinds of stone masonry is specified to be laid in clay it will be carried out as specified for mortar except that—

(*a*). The cementing material will be well tempered clay instead of mortar.

(*b*). The stone used need not to be soaked previous to use.

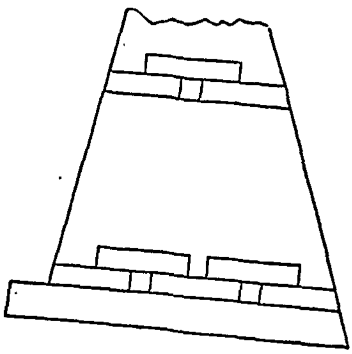
(*c*). The top course of unfinished work need not be covered with mortar.

34. The clay will be prepared as specified under Brickwork, para. 23.

35. **Dry rubble.**—All the above kinds of masonry can be carried out dry, that is, without the use of mortar. This sort of work is in very general use for breast and retaining walls in hill roads.

36. In these cases the front batter should never be less than $\frac{1}{4}$, but where base room can be obtained, it may advantageously be made $\frac{1}{2}$. The back slope should be about $\frac{1}{6}$. The coursing will always be normal to the face of the wall, and there will always be a projection or broad footing at the base. The top of the wall must not be less than 2 feet thick. In surcharged walls this thickness must be increased to 3 feet.

37. Through bond, from front to back, consisting of a single stone or of several stones put together, must be given in every course at every 5 feet along the face of the wall. Where bond stones of length equal to the thickness of the wall are procurable, they are always to be used.



38. In thicknesses beyond this limit the through bond will be given as shown in marginal sketch. Care must be taken that the spanners bear normally on the other stones, so that with the superincumbent weight, they may act truly as binders.

39. The limit of height for such walls will depend on the quality of the stone, and on the space available at the base. Unless the stone be very good, and other circumstances be favourable, they should not exceed 12 feet in height, after which mortar should be used.

Pointing.

1. When masonry or brickwork is completed, and the joints raked out to a depth of about one quarter of an inch, its faces will be thoroughly cleared by rubbing them over with a besom or rough brush made of branches of trees; no pointing is to be commenced until the raking out has been seen and passed by the officer in charge of the work.

2. Lime putty, or "fine stuff," will be used for pointing, and may be coloured, or used pure and of its original colour, as may be directed by the Executive Engineer.

3. The lime putty or "fine stuff" will consist of as pure a lime as possible, slaked with a small quantity of water, sufficient being afterwards added to bring it to the consistency of cream; it will then be left to settle in a tub. The surface water will then be drained off, and the remainder allowed to evaporate, until the putty is thick enough for use. When a hydraulic lime has unavoidably to be used, it must be ground quite fine, and to the consistency of cream, in ordinary country hand flour mills.

4. The face of the walls to be pointed must be kept thoroughly wet for two days before the pointing is commenced.

5. The joints and bed lines of each course on the face of the wall will then be covered over with a thin coat of lime putty, care being taken that the pointing is not allowed to spread over the edges of bricks, but that it is confined only to the outer surface of the joints and beds and the putty forming the pointing should not be allowed to project from the face of the wall.

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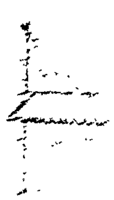

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7. [illegible]

8. [illegible]

near the sea coast or in very damp climates. It will be carried out in the same manner as lime pointing, except that instead of lime mortar pure Portland cement will be used; greater attention will be paid to thoroughly wetting the wall before the pointing is applied, and the wall must be kept wet for at least seven days after the pointing has been completed.

Plaster.

1. **Rough casting.**—Plaster will be composed of the ingredients laid down for each Division; as fat a lime as possible will be used, on account of the readiness with which it slakes into a fine powder.

2. Plaster will be laid in one, two, or three coats, as may be found necessary.

3. Brickwork will never have more than one coat of plaster, but masonry may have three, and no single coat shall ever exceed half an inch in thickness.

4. Previous to the application of the plaster, the joints of the brickwork or masonry must have been raked out to a depth of at least half an inch, and this is best done as the work progresses in construction, and while the mortar is still green.

5. After the joints shall have been raked out, the wall must be cleaned down and kept thoroughly damp for two days before the plastering is commenced.

6. The plaster may then be applied; and, before each coat sets, it must be well beaten with long thin laths, (to consolidate and compress the mortar,) until such beating makes no impression on the surface.

7. When two or three coats are ordered, the first must be allowed to completely set before the second is laid, and the surface should be left rough, and freely scored all over with the edge of a trowel, to prepare it for the next coat.

8. If it be thought desirable, the plaster may, during the process of beating, be well sprinkled with a mixture of 3½ seers of *gúr* (coarse sugar) dissolved in half a commissariat beer cask of water, to which may be added 2 seers of bael fruit; this will quicken the setting of the mortar and improve the quality of the plaster.

9. **Floating.**—After the "rough cast" has been applied as above in the number of coats directed or specified, and has become quite firm, the next operation will be "floating," which will be done with a long straight-edge called a float.

10. A sufficient quantity of fine plaster should be thrown on the wall, so as to allow of its being brought to a completely smooth surface, by drawing over it the plasterer's float backwards and forwards.

11. **Rendering or setting coat.**—As soon as the surface is perfectly true and level, and quite dry and set, it will be "rendered" quite smooth by having lime putty spread over it with the face of a large trowel, with which it must be rubbed in until it becomes perfectly smooth and even.

12. In order to guard against the setting coat showing numberless fine cracks all over its surface, as frequently happens from the unequal shrinking of the different coats, it should not be applied till the previous coat is quite dry, otherwise, being very thin, it will harden from exposure to the air before that previously laid has done shrinking, the result being that, if there is a proper adherence between the two coats, the setting coat will be disfigured by numberless fine cracks; whilst, where the coats have not adhered well together, hollows will be found, and the setting coat will be liable to come off at those spots.

13. **Mud Plaster.**—Mud plaster will be composed of stiff clay and chopped straw in the plains, and of stiff clay and pine spines in the hills in equal proportions in bulk. The clay after being excavated is to be spread out to be scorched by the sun. It is then to be reduced to powder and stacked in heaps of 100 cubic feet or as required.

14. The straw will then be thrown over the clay and mixed with phowrahs in a dry state till thoroughly incorporated. Water is then to be added, and the whole left for two days to soak. It will then be mixed with the feet and phowrahs, water being added as required till it assumes the consistency of stiff mortar.

15. It will then be spread evenly over walls or roof with the hand or trowel to the thickness of 1 inch on roofs and $\frac{1}{2}$ to $\frac{3}{4}$ inch on walls, and be floated to an even surface with a straight-edge about 3 feet long. The plaster will then be allowed to dry, and the cracks that open out during the process of drying will be filled in with liquid cow-dung.

16. **Leeping.**—The surface will then be leeped over with a mixture of cow-dung and clay. This will be done by hand on roofs, and by trowel and float on walls. Care will be taken to preserve all lines, mouldings, &c., that existed previously.

17. The cow-dung is prepared by first steeping it in water to free it from grass, straw and other impurities, then one cubic foot of finely

powdered clay is added to one cubic foot of cow-dung, and both ingredients are mixed in a tub and thoroughly worked up together.

18. Before giving a new coat of plaster to any roof, the orders of the Sub-Divisional officer shall be taken as to whether he wishes more removed from the roof than the old coat of plaster. This will usually be the case if the roof covering be thicker than 6 inches on main roofs, and 4 inches on verandahs and minor buildings.

Whitewash.

1. **Preparation of walls.**—The walls will be thoroughly cleaned down and freed from all foreign matter before the whitewash is applied.

2. In special cases when it is considered necessary to remove the old whitewash, or to scrape the walls, this work must be separately specified.

3. **Wash.**—The wash will be prepared from shell lime when available, otherwise from fresh stone lime slaked on the spot.

4. The slaked lime will be placed in tubs nearly full of water, and will then be mixed with the hand, and stirred up with a pole until it attains about the consistency of thin cream.

5. When sufficiently mixed, the wash will be taken out in small quantities and strained through a coarse cloth into *ghurrahs* (earthen pots).

6. Gum in the proportion of 2 chittacks to one cubic foot of lime will be added to the strained whitewash, and the whole will then be boiled together.

7. Whitewash will be laid on in three coats with a brush; the coats being laid on vertically and horizontally alternately.

8. This specification will apply to all colour-washing, the only difference being, that the colour specified or directed will be obtained by adding the necessary colouring matter to the whitewash.

9. In re-colour-washing walls, a coat of whitewash will first be applied over the old colour-wash to kill the former colour; when dry the new coat of colour-wash will be added. Care must be taken that the workmen keep the mixture constantly stirred while putting it on, otherwise the colouring matter will settle, and the work be uneven and streaky.

Floors.

1. **Floors in lower stories.—Preparation of surface.**—The plinth-filling shall first be well watered and rammed until it is completely

consolidated, and will not yield from a heavy blow with an iron road-metal rammer.

2. When the above operation is completed, a sufficient quantity of the filling will be removed, so as to make room for the flooring to be placed at exactly the height and position indicated on the plans.

3. For inner floors the excavations will be perfectly level, but in all verandahs it will be so executed as to ensure an outward slope of 1 in 40 to the flooring when completed.

4. The floorings will be of equal thickness throughout, and of the best materials locally procurable, as may be specified or ordered.

5. **Brick flat flooring.**—This will consist of 1st class pressed bricks carefully selected, unless otherwise specified, laid on 3 inches of concrete.

6. As soon as the plinth-filling is cleared out as above described, a concrete bed of 3 inches in thickness will be laid as specified under the head of "Concrete."

7. The concrete will be laid perfectly level for all inside rooms, and with an outward slope of 1 in 40 for verandahs, and the concrete in the latter shall lie 2 inches lower at the door frames than the level of the concrete in the adjacent inside rooms, the outward slope commencing from that point.

8. The concrete will be well rammed and consolidated as laid down in the specification under that head, until it shall have been reduced to $2\frac{1}{2}$ inches in thickness. Care must be taken that it is kept perfectly level where it is so indicated on the plans, and that the proper slopes, where such are indicated, are uniformly and evenly carried out; and the concrete will be kept wet until set.

9. The bricks will be laid on this concrete being bedded thereon in lime mortar. The joints between the bricks are not to exceed $\frac{1}{16}$-inch in thickness, the sides of the bricks being rubbed if necessary to give this joint. Care must be taken that the sides are worked square with the face of the brick and not tapering downwards to give a false fine joint on top.

10. When laid the surface of the floor must be perfectly even and free from any inequalities, to ensure which, it is to be wetted and rubbed over, with a hard heavy stone with a slightly roughened bottom.

11. For all brick flooring, the bricks are to be soaked in water for 24 hours before being used, and adjacent courses are to break joint.

12. **Brick-on-edge flooring.**—This will be constructed as specified

for brick flat flooring. The bricks will be $9'' \times 4\frac{1}{2}'' \times 2\frac{3}{4}''$ or $12'' \times 6'' \times 3''$ as may be ordered. They will be laid on edge.

13. **Tiled brick flooring.**—This will consist of 1st class machine pressed tiles made of tile clay $9'' \times 9'' \times 2''$. They will be laid as specified for brick flat flooring.

14. **Terraced flooring.**—The preparation of the plinth will be done as specified for brick flat flooring. The terraced flooring will, unless otherwise specified, be 6 inches thick and be laid as follows:—

15. The concrete will be composed of broken stone or broken *kunjah* (overburned) brick, the largest pieces of which will be capable of passing, whichever way they are turned, through a ring one inch in diameter. This ballast will be steeped in water for four hours before being mixed with the mortar; the mortar or ballast will be mixed in the proportions specified for concrete.

16. The mortar will be composed as specified under that head.

17. The mortar and ballast will be thoroughly incorporated on platforms specially made for the purpose as specified under the head of "Concrete."

18. When the concrete is thoroughly mixed, it will be laid in a thickness of 6 inches deep. Care should be taken that the concrete is not in too fluid a state. When laid it will be beaten with small round rammers 6 inches in diameter until it shall have been reduced to 5 inches in thickness, and until the mortar shall have partially set. While this operation is under progress, the surface should be frequently tested and kept perfectly true and even.

19. While the beating is going on, the surface of the concrete will be liberally sprinkled with water, in which *gúr* (coarse sugar) and bael fruit (wood-apple) are dissolved in the following proportions, *viz.*, $3\frac{1}{2}$ seers *gúr* and 2 seers of bael fruit to half a commissariat beer cask of water.

20. As soon as the beating shall have been completed as described, the surface will be softened by being sprinkled with pure water, and the mortar which has been brought to the surface by the beating, will then be smoothed, and rendered with the face of a trowel.

21. The surface should be worked to a very fine polish, and to assist this, fine lime putty may be used sparingly (the less the better); and as the process advances, the surface should be liberally sprinkled with water in which bael fruit and *gúr* are dissolved in the proportions mentioned in para 19.

22. No plaster is to be laid over the concrete on any account, as this, though a common practice, is often the source of great evil afterwards. The fine polished surface, which it is advisable to give to the concrete, in order to prevent the floor breaking up speedily, will be given as already described, by rendering the mortar brought to the surface perfectly smooth with the face of a trowel, and by means of lime putty sparingly used.

23. As soon as the upper surface of the floor shall have been rendered thoroughly smooth, and a fine polish given to it by the free use of the smooth surface of a trowel, it will be covered with 2 inches of fine sand or earth, which will be kept damp for 21 days.

24. Flagged flooring.—This will consist of the best stone locally procurable, such as Agra stone, as may be specified, laid on rammed earth and concrete, as specified for brick flat flooring.

25. As soon as the concrete shall have completely set, the laying of the flagging may be commenced. The flags may be of unequal sizes, but must be hard, even, sound and durable.

26. The flags will be between 1½ and 1¾ inches in thickness, never less than 14 inches wide or greater in length than 2 feet 6 inches. They

32. In the case of T-iron joists being used, they will receive three coats of Olphert's paint before the flagging is laid.

33. **Lower course of flagging.**—When wooden joists are used, all the flags will be so dressed that the shorter joints of the lower courses of flagging shall lie on the centre of every second joist, and so that there will be a joist under the centre of each flag, and the flags shall be so laid as to break joint.

34. The flagging will be laid in courses parallel to the shorter side of the room.

35. When T-iron joists are used (the flanges being always downwards) the lower course may be either of flagging or bricks, (the latter generally,) laid on the flanges of the T-iron, and completely filling up the intervals between the joists.

36. **Upper courses of flagging.**—When wooden joists are used, the upper layer of flagging will be laid in courses parallel to the shorter wall of the room, each course being of uniform width, and so as to exactly break joint in the centre of each flag with the lower course longitudinally, and with each flag in the lower course transversely.

37. In the case of T-iron joists, the lower course having been laid as specified, the upper flagging may be laid as specified for single flagging.

38. **Common to both courses.**—The position, size, &c., for double flagging of upper-storied buildings having now been described, the laying, description, thickness, and fitting of the flags, where not effected by the above specification, will be as laid down for single flagging, the lower course being laid dry, and the upper well flushed in mortar as specified for brickwork.

39. **General.**—All the above kinds of floor, except terraced, should be pointed with Portland cement. Flagged flooring is much to be preferred, but where very expensive, brick flooring may be substituted. The use of terraced flooring is not recommended, except when the better kinds cannot be adopted.

40. **Patent Stone.**—This will consist of Indian Patent Stone made with ballast obtained from that Company at Calcutta, or from ballast locally manufactured, as may be specified.

41. It will be laid as specified below on rammed earth and concrete, as specified for brick flat flooring.

42. The floor space to be laid with the stone should be first well

Note.—For Wooden floors, *see* Woodwork.

watered and rammed, and then laid over with not less than 4 inches of pucka concrete, beaten down and consolidated, till a solid unyielding bed with a somewhat rough rather than smooth surface is obtained to lay the stone upon. Any slope or fall or channel or other form required for the surface of the stone, should be prepared in the bed on which the stone is to be laid. To lay the stone, battens of convenient length and width, and of the depth or thickness to which the stone is to be laid, must be laid on the bed not more than 6 feet apart with no space between the battens and the bed, and with the depth and thickness of the battens vertical to the bed, *i.e.*, at right angles to the bed of the floor. After laying the battens on the bed, the slag and Portland cement should be thoroughly mixed in the proportion of three parts of the prepared slag to one part of Portland cement. To this mixture of slag and cement add clean water, free from all grease and clayey matter of any sort, in sufficient quantity only to form the slag and cement into a plastic mass of the consistence of builder's mortar. The bed should be thoroughly wetted with water,

brought to an approximate level by stone in mud, well rammed. A layer of mortar is next laid, and the stone hammered down with a wooden mallet to its correct level. The joints are filled with mortar in the usual way, and the stones well set one against the other. Flush pointing finishes off the work. The surfaces to be kept damp for at least 10 days after completion.

47. **Asphalte flooring.**—Will consist of asphalte, with coarse clean sand or stone grit mixed together in a caldron, and coal tar in the following proportions :—

600 lbs. asphalte, (Harrison's).
4 cubic feet of sand or grit.
$7\frac{1}{2}$ lbs. coal tar.

48. The sand or grit must be free from dust, and must be washed and screened through two screens. It should pass through a sieve of 6 meshes, but not through one of 18 meshes to the inch.

49. The proper proportion of coal tar is to be put in a caldron and heated over a wood fire ; the asphalte broken up fine is then to be gradually added, the mass being kept well stirred.

50. When the asphalte and coal tar are thoroughly mixed and melted to a liquid state, the sand or grit after being freed from moisture is to be gradually added, the whole being stirred till the preparation is ready for use.

51. Strict supervision is required in mixing, to prevent too large a proportion of the coal tar being added. Workmen are tempted to do this as the asphalte when so mixed is laid with greater ease, than when the proper proportions are used.

52. When the preparation is ready for use, the boiling mixture is to be taken from the caldron with an iron ladle and laid on in rectangles $8' \times 2'$ between wooden gauges, and spread evenly with a hot trowel to the requisite thickness. After one piece is spread the surface is to be sprinkled with clean sand, and rubbed smooth with a hard wood rubber. The gauges are then to be removed and the process continued.

53. Before a fresh piece of asphalte is spread, the edge of the spread asphalte is to be melted by passing a red hot iron over it, to make the connection between the two pieces perfect. Should there be a defect in any joint, live charcoal should be placed on the part to soften the asphalte, and if necessary fresh asphalte added, and the part rubbed smooth with a hot trowel or hard wood rubber.

54. **Clay flooring.**—This will be laid in layers of 6 inches to the requisite depth, and will consist of stiff clay broken up into powder and well rammed with water. The surface will be finished with a coat of mud plaster, and leeped with cow-dung as specified for mud roofing.

Woodwork.

1. **Framing.**—Woodwork will be of teak, sál, deodar, chir, or other sound wood locally procurable as specified.

2. All wood used must be thoroughly seasoned, completely free from sapwood, large knots, shakes, and other defects.

3. The framing or timbers will be dressed and planed to the full dimensions shown on the drawings, or as directed by the Executive Engineer.

4. **Joints, &c.**—Great care must be taken that all *mortise and tenon joints, scarfs, &c.*, fit fully and truly. In order to guard against careless workmanship or failures from decay, joints are to be designed, as far as possible, so that the bearing surfaces or working parts are thrown to the outside and exposed to view. Simple joints, being much more likely to be truly and securely made, are always to be used in preference to more elaborate ones. Joints will always be coated with white lead before the frames are finally put together.

5. In constructing trusses a drawing of the truss, full size, is first to be made on a level platform, from which templates of all tenons, mortises and scarfs, &c., are to be made as a guide to ensure all the trusses being of the same size.

6. Timber buried in the ground should be charred and tarred. Woodwork exposed to the weather should be tarred, varnished, oiled, or painted, if the wood is seasoned, otherwise it should be allowed to remain until seasoned, as coating it will do more harm than good by confining the natural juices of the wood, and will only hasten the decay of unseasoned timber.

7. No woodwork is to be placed in position in a building or painted until approved and passed by the Executive Engineer or the person whom he may depute to do this duty.

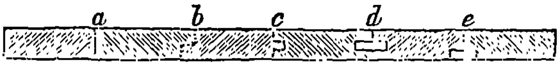
8. The ends of all beams, &c., which are to be bedded in walls, and the sides of timbers which are to abut against walls, shall receive three coats of coal tar laid on hot.

9. Where the end of a beam, or any woodwork, is buried in masonry or brick work, an air space of $\frac{3}{4}$-inch should be left all round.

10. **Floors.**—Wooden floors in upper storied buildings will be laid on wooden flooring joists, supported on wooden beams or iron girders, as shown in the drawings.

11. The upper surface of the joists must receive three coats of coal tar laid on hot, to prepare them for the boarding.

12. The boards, after having been dressed and planed perfectly square, true, and smooth, with parallel sides and ends, will be placed side by side, and their edges jointed by one or other of the following joints; the one to be used being specified in each case—*viz.*, *shot* (*a*), *rebated* (*b*), *grooved and tongued* (*c*), *grooved and filleted* (*d*), *rebated and filleted* (*e*).



13. Their ends will always rest on a joist and may be shot. The ends of no two boards next each other are to come together.

14. They will be cramped into position by means of a carpenter's cramp, which is always to be used. The cramp will not be removed until the nails have been fixed.

15. The length of each board is not usually to exceed 8 feet, or its breadth 6 inches; nor must its thickness be less than $1\frac{1}{2}$ inches.

16. All boards will be fastened to joists and beams with nails or spikes of a length $2\frac{1}{2}$ times that of the thickness of the board. The nails will interspace one another, each being spaced at one foot intervals.

17. The rebates and fillets must be well coated with marine glue before the boards are laid, and care should be taken that the fillets fully fill the rebates cut for them. The edges of the boards should also be painted with marine glue.*

18. **General to all floors.**—After the floors have been laid, they must be carefully planed over, and made perfectly true, level, and smooth.

19. All special floors, such as double-boarded, or double-boarded with felt between, &c., must be specially specified.

20. **Ceilings.**—Wooden ceilings will be constructed with boards half an inch thick, of teak, deal, deodar, huldu, or any other wood as specified, the ceiling being fixed as shown in the plans.

21. The boards will be *shot, rebated, or grooved and tongued,* as shown

* *Marine glue.*—Dissolve by heat one part of pure Indian rubber in naphtha; when melted add two parts shellac; melt until mixed.

above, as may be specified. They will be planed and dressed quite smooth, and free from all inequalities.

22. When the ceiling has been secured in position, it will receive three coats of good varnish, or it may be painted.

23. Cloth ceilings may be provided when considered desirable. They will consist of good strong double warp cloth like that supplied by the Elgin Mills Company at Cawnpore, the breadths of which will be well and strongly sewn together.

24. The cloth will be tightly, firmly, and smoothly stretched, when damp, on frames of convenient size, which will be secured to ceiling joists or the roof timbers, as shown in the drawings, or as directed or specified by the Executive Engineer.

25. These frames will be prepared on the floor and placed in position when ready.

26. When the cloth shall have been fixed as above specified, it shall receive three coats of whitewash prepared from whiting; lime should not be used.

27. **General.**—The contract rates will include all lifting and fixing in position of timber, with the cost of all necessary scaffolding, ladders, tackle, nails, spikes, &c., that may be required for the proper execution of the work, also the cost of the fitting of all ironwork.

28. All carpenters' work in position will be paid for by net measurements, no allowance being made for wastage, nor for dimensions supplied beyond those ordered.

Doors and Windows.

1. **Panelled and glazed doors.**—The frames or chaukhats of these will be of teak, sál, deodar, chir, or other kinds of wood, whichever may be most suitable or economical, as specified; they will be secured to the walls as shown in *Plate* XIII.

2. The *stiles*, *rails*, and *panels* of all doors and windows will be of teak, deodar, or chir, as directed or specified; they will be of the full dimensions shown on the drawings, and will be accurately and truly fitted in all their joints, which are to be put together with marine glue, *see* footnote page 26.

3. **Battened doors.**—These will be made in two leaves of sound teak,

deodar, chir, or other wooden planks, 1 to $1\frac{1}{2}$ inches thick as specified, nailed or screwed together longitudinally and transversely.

4. **Windows.**—Glazed windows will be made of teak, deodar, chir, or other wood as specified. The sashes are to be made to fit the sizes of panes obtainable in the market, usually 8×10 or 10×12 inches. Particular care must be taken with the connections of the sash bars to ensure that they are accurately fitted.

5. Windows will be hung either to swing on central pivots as with clerestory and fan lights, or will be hung on two leaves with two hinges to each leaf.

6. **Hinges.**—Doors and windows will be hung with one of the descriptions of hinges shown on *Plate* LVI., the particular hinge to be used being specified.

7. Butts are to be countersunk, and the stile of the door must be beaded, so as to hide their ends when shut, as shown in *Fig.* 1. Their length in inches should be specified.

8. When doors are in several leaves which have to be folded back against each other, back flap hinges are to be used.

9. When the stuff is too thin to admit of butts being screwed on to the edge of the stiles, or when it may be desirable to strengthen the points of connection between the rails and the hanging stile, as in the case of the door shown on *Plate* LIV., H, HL, or cross garnet hinges may be used.

10. For gates and heavy outside doors, as to gun sheds, hook-and-eye hinges are to be used, the hook being screwed right through the frame, and secured with nuts.

11. **Locks.**—Iron rim locks will be used for all ordinary barrack purposes where locks are required, but in barrack rooms a hasp and staple carrying a padlock is generally sufficient. For magazines, locks will be of copper. Their length must be specified in inches, as also whether right or left hand locks be required.

12. If for special purposes a better class of lock be required, it must be specially specified.

13. **Furniture.**—The furniture, such as handles, must be strong and well secured; stout ring handles are to be preferred to knob handles, which latter must be cast or filled in solid to prevent their being indented.

14. The keys should have solid bows, or if they be ring keys, with an

open bow, it must be filled in with brass before issue. The bow should be engraved or stamped with M. W. on one side and with the number of building or room on the other.

15. Each door or window will be furnished with one or more best barrel bolts per flap, as shown in *Plate* LV. Their length must be specified in inches, and the upper bolt must be of such a length as to be within easy reach of a man standing on the floor. The crams must always be fixed with two screws on each side. When a better class of bolt is required, it must be specially specified.

16. For out-offices, and where otherwise specified, the Norfolk thumb latch, large, middling, or small, will be used.

17. In loose boxes of stables, horse infirmaries, and localities in which projections are inadmissible, flush latches will be used.

18. **Glazing.**—The rebate for glass on the outside of a sash bar shall never be less than three-quarters of an inch in depth, and $\frac{3}{8}$-inch in width ; standard sizes of panes will be used, and the distance between the rebates must always be very slightly in excess of the glass ; the latter is nowhere to touch the woodwork of the frame, otherwise any jar to the frame would be liable to crack it.

19. The whole sash bar, but especially the rebate which is to receive the putty, will first be well primed, to prevent the wood drawing the oil out of the putty. The glass will then be firmly bedded on putty, or "front puttied."

20. The glass will be secured in the rebates by 'back putty' sloping from the inner to outer edge of rebate. The back putty must be kept a little within the inner edge of the rebate, so that none of it may show through the glass from the inside. Both front and back putty is *at once* to be covered with a coat of paint, to prevent it shrinking as the oil dries out of it. Each pane will be further secured in position by four iron brads, one in the centre of each side. These are always to be completely hidden by the back putty. Panes of glass should weigh not less than 21 ounces per square foot.

21. The glazing of vertical frames must be upright.

22. **Putty.**—Putty will be made of perfectly dry whiting well kneaded up with raw linseed oil. It should be well rubbed and beaten before being used. In mixing the putty, a little white lead may be added to strengthen its adhesive powers, and to give it greater hardness ; or the receipt on page 54 may be used.

Ironwork.

1. All wrought-iron articles are to be manufactured from iron equal in quality to best Staffordshire, or of mild steel, and to be approved by the Executive Engineer before being fixed. They are to be forged clean from the anvil, and neatly, soundly, and perfectly finished. For any special work a special specification must always be given.

2. All edges must be filed square when directed, and all bolt and rivet holes may usually be punched, but they must be drilled out if required.

3. All bolts and nuts will be neatly and fairly worked to the full dimensions of the gauges in use in the Executive Engineer's workshops. The gauges must be those of some recognized authority ; those supplied by the Canal Workshops, Roorkee, are recommended. The screws of bolts should not project more than one thread beyond the nut when the latter has been screwed up.

4. For cutting and tapping bolts and nuts, Whitworth's taps and dies will always be used ; and the thread will be full, true, and deep, without taper, and accurately fitted.

5. Iron tie-rods, when they run through a shoe and are screwed up at the back, will be thickened by the depth of the thread to be cut on them, and this thickening will be gradually worked off.

6. All rivets must fit fully and truly ; the holes made for them must be of the sizes, and in the positions, shown on the drawings ; and if the rivets shake at all from the blow of a hammer, they must be cut out and replaced.

7. All castings must be clean and sound, and entirely free from air holes.

8. Every Executive Engineer will establish one or more workshops, where all the ironwork required for his Division will be made up. The practice of allowing contractors to make up ironwork in the bazars, and passing it from them to the works, is prohibited.

9. All ironwork will be paid for, and agreed for, by the cwt., and not by the maund.

See also under Painting.

NOTE.—A more detailed specification for ironwork ordered from local firms will be found in Appendix C. of Military Department letter No. 1681F of 25th June, 1898, reprinted on pages 57-65.

Painting.

1. **Woodwork, new work.**—Woodwork is always to be painted unless otherwise specially specified. If wood be not properly seasoned and free from moisture, the coating of paint or varnish, by confining the moisture to its pores, will lead to its decay from dry rot. All woodwork to be painted should therefore be well seasoned and dry, and the painting should always be carried out at the driest season of the year.

2. The paint used will be the best silicate paint, unless otherwise specified, and it may be mixed somewhat in the following proportions, the quantity of oil varying according to the dryness of the paint:—

Ingredients.	Priming.	1st Coat.	2nd Coat.
Silicate paint, ...	*See* para. 5,	7 lbs., ...	7 lbs.
Boiled linseed oil, ...		3⅛ pints, ...	4½ pints.
Driers, ...		1 lb., ...	1 lb.
Turpentine, ...		1⅜ pints, ...	*

3. **Mixing.**—The mixing of the ingredients will be carried out as follows:—The oil and turpentine will be first mixed, and added to the paint, and the whole thoroughly mixed with the hands, the paint being well rubbed between the palms until no lumps remain. It will then be strained through a piece of fine cloth (*dhútwi* or *guzi*). The driers are only to be added just before using.

4. **Preparation of woodwork.**—Before applying the paint the woodwork must be thoroughly cleaned, all projections removed, knots or holes covered, or filled in, with a preparation of red lead and glue size, laid on hot, called knotting. With resinous woods, such as deodar, this should be done by painting them over with hot lime. After 24 hours the lime is scraped off, and the knots painted with red and white lead and linseed oil. When dry they will be pumice-stoned smooth.

5. **Priming coat.**—The priming coat composed of white and a little red lead, mixed with raw linseed oil, and a little litharge ground very fine in turpentine, will then be applied, and when this is quite dry, all cracks or holes are to be filled up with putty, and the whole surface rubbed down with pumice stone, or glass paper, and well dusted.

6. **Second coat.**—The second coat will then be laid on in exactly

* For last coat on inside work, some turpentine should be added.

the same manner as the priming coat, and when dry the surface will be rubbed down with pumice stone, or glass paper, and well dusted.

7. **Third coat.**—The third or final coat will then be applied in the same manner as the preceding ones, greater care being necessary to prevent brush marks being visible on its completion.

8. **General.**—The paint will be applied with brushes, and spread as evenly and as smoothly as possible. To effect this, as soon as the whole or a convenient quantity is covered, the brush should be passed over it in a direction contrary to that in which it is finally to be laid off; this is called *crossing.* After crossing, it should be laid off softly and carefully in a direction contrary to the crossing, but with the grain of the wood, taking care that none of the crossed brush marks be left visible. The criterion of good workmanship is, that the paint be laid evenly, and the brush marks be not observed. In *laying-off*, the brush should be laid in to that portion of the work already done, so that the joining may not be perceived. Every coat should be perfectly dry, and all dust carefully removed, before the succeeding one is laid over it.

9. The paint must not be allowed to settle in the cans; to prevent this each painter will have in his tin can a small smooth stick, with which he must be made to stir up the paint occasionally. If it has to be laid on one side for a time in an open vessel, it should be covered with water to prevent oxidization and drying.

10. In painting doors and windows, the putty round the glass must also be painted, and after the completion of the final coat, all the glass will be cleaned; stains from paint, &c., being removed by the application of a little turpentine.

11. **Old work.**—The old woodwork will be well rubbed down with pumice stone, greasy places being rubbed with turpentine. All projections having been removed, the woodwork will then be washed with soap and water. All holes and cracks will then be filled with putty, any patches or blister marks to receive a priming coat.

12. As soon as the wood is thoroughly dry, silicate paint, unless otherwise specified, mixed as described for new woodwork, will be laid on in two coats, in the manner specified in paras. 6—10.

13. **Ironwork.**—All ironwork is to have the surface protected from rust before the work leaves the Executive Engineer's workshop; for when once the metal begins to oxidize, the process is most difficult to arrest. Paint or other protecting coat will peal off, if applied to a surface con-

forms specially made for the purpose, as specified under the head of "Concrete."

6. **Consolidation.**—When the concrete is thoroughly mixed, it will be laid on the flagging in one thickness of 6 inches deep. Care should be taken that the concrete is not in *too fluid* a state. When laid, it will be beaten with small round rammers 6 inches in diameter, until it shall have been reduced to 5 inches in thickness, and until the mortar shall have partially set. While this operation is under progress, the surface should be frequently tested, and kept perfectly true and even in the line of the outward slope specified, *viz.*, 1 in 20.

7. Two rows of coolies will next be placed on the roof along its entire width as close as they can sit, and will traverse the length of the roof backwards and forwards, beating with what is called a *thápí* (a wooden knife of the shape shown in the margin). This beating will continue until the mortar shall have almost set and until the *thápís* rebound from the surface readily when struck on it. This will usually be attained after three days.

Elevation. *Section.*

8. While the beating is going on, the surface of the concrete will be liberally sprinkled with water, in which *gúr* (coarse sugar) and *bael fruit* (wood apple) are dissolved in the following proportions, *viz.*, three-and-a-half seers of *gúr* and two seers of bael fruit to half a Commissariat beer-cask of water.

9. **Rendering surface.**—As soon as the beating shall have been completed as described, the surface will be softened by being sprinkled with pure water, and the mortar which has been brought to the surface by the beating will then be smoothed, and rendered with the face of a trowel.

10. The surface should be worked to a very fine polish, and to assist this, fine lime putty may be used *sparingly* (the less the better); and as the process advances, the surface should be liberally sprinkled with water in which bael fruit and *gúr* are dissolved in the proportions mentioned in para. 8.

11. **Surface.**—No plaster is to be laid over the concrete on any account, as this, though a common practice, is often the source of great evil afterwards. The fine polished surface, which it is advisable to give to the concrete, in order to allow of water running off speedily, will be given, as already described, by rendering the mortar brought to the surface perfectly smooth with the face of a trowel, and by means of lime putty sparingly used.

12. **Watering.**—As soon as the upper surface of the roof shall have been rendered thoroughly smooth, and a fine polish given to it, by the free use of the smooth surface of a trowel, it will then be covered with 2 inches of fine sand or earth; and over this again will be placed a layer of grass mats, which should be kept thoroughly saturated with water until the rains shall have commenced.

13. Junctions of terraced roofs with main clerestory walls will be secured by a drip course of the standard pattern, or when the wall has already been built, by a laying a floor of roofing bricks 2 feet wide on the terrace, and let 3 inches into the main wall.

14. The eaves, except otherwise ordered, will be finished off with a plain cornice, formed of projecting bricks, and plastered; or with a dwarf parapet wall and plaster reveals, or cast-iron down-pipes down the walls.

15. **Mud roofing over bricks.**—Terraced roofs are not suitable for dry climates like the Punjab; they invariably crack in the dry weather and leak badly when rain comes on. Hence it is better to use mud over bricks laid as follows:—

16. Mud roofing over bricks will consist of 6 inches of well tempered clay consolidated over roofing bricks $12'' \times 6'' \times 2''$ which will be laid dry over sawn rafters spaced at one foot central intervals, or will be jointed with mortar as may be ordered.

17. The clay must be stiff white or red clay according to locality, and after being excavated is to be spread out to be scorched by the sun. It is then to be reduced to powder, and stacked in heaps of 100 cubic feet.

18. Water is then added and the clay is well mixed by treading with the feet and with phowrahs, until the whole assumes the consistency of stiff mortar.

19. It is then laid on the roof and well beaten until quite hard. It is then finished off with a coat of mud plaster, and leeped with cow-dung as described in the specification for mud plaster.

20. **Allahabad Tiling.**—A full description of the manufacture of Allahabad Tiles will be found in the "Roorkee Professional Papers," Vol. III., 2nd Series, page 146, by Major G. P. de P. Falconnet, R.E. The tiles should, however, always be burnt in Bull's Trench Kilns, the latest patterns of which are described in his pamphlets printed at Lahore.

21. Single or double Allahabad tiling will be used as specified or as directed by the Executive Engineer. In districts where high winds prevail

this kind of roofing is unsuitable without a ceiling cloth, as it lets in hot air too freely in summer and cold air in winter with intolerable quantities of dust at both seasons. This can be remedied to a great extent by using the pattern of flat tile shown in *Plate* LXX. in the lower layer set in clay and lime pointed below.

22. **Double Allahabad Tiling.**—Double tiling will be laid as shown in *Plate* LXIX., and will consist of layers of flat tiles laid on battens, the latter being secured to the common rafters. The side edges of every two adjacent flat tiles will be covered by a semi-hexagonal tile; over these semi-hexagons will be laid another layer of flat tiles, the adjacent edges of every two of the latter being again covered by a semi-cylindrical tile.

23. **Single Allahabad Tiling.**—Single tiling will consist of a layer of flat tiles laid as described for the lower layer of double tiling, but having the adjacent two edges of each row covered with a row of semi-cylindrical tiles.

24. **General.**—All tiles used must be thoroughly burned, of uniform colour, and free from twisting and other imperfections. They must be of a dark red colour, and must ring clearly when struck. The three lowest tiles in each layer, over the walls and next the eaves, will be set in fine mortar.

25. All tiles must fit closely and well, in the position shown in *Plate* LXIX.; the moulded niche at the lower end of each flat tile fitting completely into the head of the tile next below it, and the buttons at the upper end must have a firm hold on the wooden battens, placed at one foot intervals, to receive them.

26. Each semi-hexagon must fit exactly in its position, both on the flat tiles under it and also into the bed specially formed in the upper part of the next semi-hexagon to receive it.

27. The upper layer of flat tiles must be exactly the thickness of the semi-hexagon. They will then exactly overlap each other by 3 inches, and yet fit in the position made for them on the semi-hexagonal tiles, the lower buttons taking the lugs moulded on the sides of the semi-hexagons to receive them.

28. Over this upper layer of flat tiles, and covering the two adjacent edges of every row, will be laid a row of semi-cylindrical tiles, which must again fit exactly on to the flat tiles, the shoulder of the niche cut out of each coming close in contact with the lower edge of the flat tile under it,

and the buttons towards the lower end will exactly lie on the upper edge of the semi-cylindrical tile next beneath it.

29. The ridges, and hips when existing, will be covered by the tiles specially manufactured for these positions, and as shown in the drawings in Major Falconnet's article.

30. The three lowest tiles in each course, also all ridge and hip tiles, will be set in fine sound mortar, and will be well watered for five days after laying; but no mortar is on any account to be used in any other part of a tiled roof.

31. A wood rasp may be used in making the tiles fit completely and closely, but any tile which cannot be made to fit with its neighbour closely, without injury from rasping, must at once be rejected.

32. When the roof covering is completed, all the lines of the tiling must be perfectly even and straight. This will best be observed by noticing the diagonal lines made on the roof by the end of the semi-cylindrical tiles.

33. For specification and instruction as regards the manufacture of bricks and tiles, Major Falconnet's article above referred to should be consulted.

34. **Mangalore Tiling.**—This tiling will be of thoroughly burnt Mangalore tiles of the Basel Mission make, laid fair and square and properly fitting, with the catches resting fully against battens nailed $12\frac{1}{2}$ inches from centre to centre to the upper surface of the rafters, and exactly at right angles to their direction. Care must be taken that each course is laid perfectly parallel to the rafters.

35. Below the channel of edge of the lowest or eaves row of tiles a batten of extra thickness is to be used to make the slope even and continuous from ridge to eaves.

36. The ridge and hip tiles will be set in the best lime mortar; and where high winds prevail, the ends of the eaves tiles will be nailed with iron nails or secured by wire to the eaves batten, unless the eaves are bedded on to a masonry cornice, or a planked ceiling is given below them.

37. In excessively wet places it is advantageous to well coat the beds or channels of the tiles with tar.

38. To make a Mangalore tiled roof absolutely water-tight, a planked ceiling should be given below the tiles to be covered with strong dungry cloth laid in lengths parallel to the boards, and each width overlapping

that below it at least 3 inches. The whole to be well tarred. *See Plates* LXXI and LXXII.

39. **Corrugated Galvanised Iron Roof Covering.**—The corrugated iron will be of the gauge specified by the Executive Engineer. The surface of the sheets must be clean and bright and free from rust. Any sheets showing a white powdery deposit should be rejected.

40. The purlins to which the sheets will be fastened will run in horizontal lines along the length of the roof. There should be one at each end, and one in the middle of each sheet. These should not be of deodar as it corrodes zinc.

41. Each sheet will be laid on the roof with a lap of 6 inches in its length : the side laps will extend over two corrugations, when the latter are small, and over one when they measure about 5 inches or more. The use of sheets having large corrugations is, however, to be avoided.

42. The sheets should be rivetted together in sets on the ground. Generally three sheets in length, and three or four in breadth, can be completed on the ground, before they are hoisted on to the roof.

43. In rivetting up the sets, the sheets should be placed on trestles about 2 feet high, so that men may be able to work comfortably underneath. The rivet holes must be punched from below, upwards, so that the arris may be at the top. The tools must be very sharp, so that there may be no tearing of the sheet, and the hole must be clean punched out.

44. These rivet holes will be placed at from 1 to 2 feet intervals along the edge of the lengths of the sheet, or at such distance approximating to above, as will equally divide the sheet along its length. At the tops and bottoms, each sheet will be rivetted at the corners, and at least once in its breadth.

45. At the corners, where the rivets have to go through four sheets, it is better to drill the holes from below. All holes will be in the ridges, and never in the gutters of the corrugations.

46. In fixing the rivets, which will always be of galvanised iron, they will be passed through from below, and held up firmly by a bolster resting on a block of wood placed on the ground. A leaden washer fitting tight to the shank of the rivet, and extending ½-inch all round beyond the edge of the hole, will be put on, and the rivet head will be made over it with a light hammer, and finished off with a capping tool. Great care must be taken that the sheet be well supported underneath, and that no indentation be made on the upper surface of the corrugation.

56. The sheeting will be laid on planking of chir, deodar, or other wood of the thickness specified. The planks in barrack roofs will touch each other laterally, and in subsidiary buildings be spaced at intervals equal to their breadth. The planking will be secured to the rafters by 3-inch screws, spaced as may be directed by the Executive Engineer. If corrugated iron sheeting be used it may be laid on purlins spaced as directed in para. 40 of the foregoing specification.

57. The battens B (*see Plates* LXXIV., *Figs.* 2 and 5, and LXXV.) $2'' \times 1\frac{1}{2}''$ will be secured to the planks by screws 3 inches long, and 3 feet apart, driven from below. The ends of the battens at the eaves will be rivetted through to the planking, with an iron rivet $\frac{3}{8}$-inch diameter, with washers $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{8}''$ at each end of the rivet (*see* C, *Plate* LXXV.).

58. The sheets will have their longitudinal edges curved, by first hammering them with a wooden mallet, with a curved head, on a wooden platform ; the other side of the sheet being gradually elevated, until the edge under treatment has assumed the form required approximately. The edge is then finished off, by being hammered with the same mallet round a wooden bar of the required shape. The sheet thus prepared will be placed on the roof, and will be secured to the planking at its upper edge by one $1\frac{1}{4}$-inch screw (*see* F, *Plate* LXXV.) placed $1\frac{1}{2}$ inches from the upper edge of the sheet, and half way between the battens. The sheets are held down at their edges by three iron clips $3\frac{7}{8}'' \times \frac{3}{4}'' \times \frac{1}{4}''$ (*see* E, *Plates* LXXIV., *Fig.* 1 and LXXV.) countersunk into the battens. The clips are made from the iron bands, which are used to bind the bundles of iron for transport, and will be screwed down to the battens with $1\frac{1}{2}$-inch screws, $\frac{1}{2}$ an inch apart in the clear.

59. The rolls or covering strips (*see* A, *Plate* LXXV.) will be of plain sheet iron, galvanised or not to accord with rest of roof, of 22 B. W. G. The strips will be hammered round a wooden bar of proper shape with the wooden mallet mentioned in para. 58, and when nearly of the shape required, an iron ring of proper shape will be placed over the roll and wooden bar at one end, and hammered down the bar to the other end, thus forcing the roll to assume the exact shape of the wooden bar. The rolls will then be slipped on to the battens, and each secured by one $1\frac{1}{2}$-inch screw (*see* H, *Plate* LXXV.) placed $1\frac{1}{2}$ inches from the upper edge of the roll.

60. The ridge will then be covered in with specially shaped ridging or

plain iron sheeting, galvanised or not to accord with rest of roof, of 18 B. W. G. These sheets will be 2 feet wide, and will be curved along their upper edges in the manner described in para. 58. They will be laid on the battens supporting the rolls, or on planking screwed to the battens, overlapping each other longitudinally by 9 inches (*see* G, *Plate* LXXV.); the joint or overlap being set in white lead. To secure these sheets, clips KK, 13″ × 1″ × $\frac{3}{16}$″, will first be screwed down to the battens (through the planking) with two 2-inch screws (*Plates* LXXIV., *Figs.* 1, 2 and LXXV.). The lower edge of each sheet will then be inserted in the clips, and the upper curved edge of the sheet brought against the ridge pole, where it will be secured in the manner described in para. 58 (*Plate* LXXIV., *Fig.* 1), thus leaving neither screws nor rivets exposed. A wooden fillet 5″ × 1½″ × ¾″ should be inserted under the end of the rolls A to prevent the screws holding down the clips K flattening them out (*Plate* LXXIV., *Fig.* 1). The special shaped ridging if used will be fixed by its edges by similar clips as described above, and if considered necessary will be further secured by galvanised iron screws to the ridge plate.

61. The ridge sheets being fixed will be covered by a roll similar to those specified in para. 59 running along the whole length of the ridge (*Plate* LXXIV., *Fig.* 1).

62. Each sheet and roll at the eaves must be held down by an iron clip, (*see* L and M, *Plates* LXXIV., *Figs.* 3, 4 and [illegible]) screwed to the planking, and passing over the end of the sheet or roll. [illegible] clips L should be given to sheets more than 2 feet wide. This is to prevent the wind getting between the sheet and the planking and raising the former up at its lower extremity.

63. When ungalvanised iron is used in the [illegible] of the roof the roof covering will receive two coats of [illegible] paint [illegible] as specified under "Painting," *after the surface has been thoroughly cleaned* and all signs of rust removed by scraping and [illegible]. [illegible] done in fine dry weather.

64. The drawings given in the [illegible] (*Plates* [illegible] LXXV.) are for plain sheets [illegible]

[illegible]

1. Gutters or flashings [illegible] superficial foot, [illegible]

7. The sectional area of a conductor or mass of conductors leading from any possible striking point to a main earth connection must, if of copper = 0·13 square inch, and if of iron = 0·8 square inch. The most usual sizes for conductors of full power are—copper tapes $1\frac{1}{2}'' \times \frac{1}{8}''$ or iron tapes $2'' \times \frac{3}{8}''$.

8. There is no reliable rule concerning the area of protection given by a conductor of given height. Any object to be thoroughly protected from lightning, must be furnished as described with proper conductors.

9. Conductors even on the most important magazines can be spaced at intervals of 50 feet, but no point on the building should be more than 25 feet horizontally distant from a lightning rod.

10. When a chimney or other inaccessible erection has to be protected from lightning, the best plan is to carry a continuous conductor of half power up one side and down the other, to use two earth connections, and to employ a connecting conductor just above the ground line, as shown on *Fig.* 4, *Plate* LXXVI., and also one round the outside of the top of the cap, and a few inches below it with terminals projecting 1 foot above the top of the shaft at intervals of 3 or 4 feet all round.

11. The angles and prominent portions of a building being most liable to be struck, the lightning rods should be fixed on gable ends, chimney turrets, &c., and they should be connected together by continuous conductors along ridges.

12. In all situations where several conductors are joined in one system, the vertical conductors should be connected both at the top and near the ground line. The horizontal conductor used for the latter operation should be carefully connected to the earths, and all the joints to it should be above ground, both for inspectional purposes and to prevent local galvanic action.

13. Lightning conductors should be connected to any outside metal on the roof or walls of magazines, and especially to the feet of metal rain water pipes.

14. In barracks with iron roofs, such as those in hill stations, the conductor may consist of a strip of galvanised sheet iron 12 inches wide by $\frac{1}{16}$-inch thick, fixed to each corner of the building, rivetted and soldered to the underside of the roof covering at the eaves. The strips will run down the walls, and be fixed by small iron staples let into the joints of the mortar at intervals of about 1 foot. Where masonry chimneys exist, a strip 6 inches wide must pass over the top of the chimney, and

17. The connection between the lightning rod and the conductor is made by means of a slotted clamp similar in design to those employed for test or other joints. The lightning rod terminates at its lower extremity in a $\frac{3}{4}$-inch bolt, which is screwed into the clamp, thereby making firm contact with one or more tapes inside it. This joint admits of visual inspection. (*See Plate* LXXVII).

18. Earth connections are of two kinds—deep and surface. In important cases both kinds should be provided, unless the permanent water level is very near the surface. The reason for this being, that sometimes (after drought) the induced earth charge is collected on a damp substratum, when a deep earth is necessary; and sometimes (after rain) it is collected on the surface, when a surface earth is necessary. A deep earth will generally be a well or at least permanently damp soil. If a well it should not be less then 3 feet in diameter, and be carried down 10 feet below water level in the driest seasons. The bottom 10 feet should have no mortar or cement in the walls. The conductors will be led into the well, and rivetted and soldered to a plate resting at the bottom of the well of at least 24 square f[illegible] conductors are of copper,

Correction to Military Works Handbook.

Page 45, paragraph 18, line 17, *for* "33 feet" *read* "100 feet."

About 33 feet of tape is required for this connection which obviates the necessity of any underground joint. Iron water pipes answer admirably as deep earths, but gas pipes must not be used as such, as accidents have been occasioned by a lightning discharge along a gas main breaking the pipe at the joints, and igniting the gas.

100

19. When neither a well nor iron water pipes are available for a deep earth, the conductor must be carried down to the dampest soil available in the manner described below. The conductor must be bent and carried away from the building along the bottom of a trench 4 feet deep for a distance of not less than 30 feet; at this point a circular pit 4 feet in diameter is to be dug, across the middle of the bottom of which an earth plate is to be set up vertically, and connected in the usual way with the conductor. The pit on both sides of the plate is to be filled up with charcoal or coke to the level of the upper edge of the plate. In cases where permanently damp soil is not to be obtained, a pipe may be carried up from the centre of this mass to the surface of the ground, and earth

filled in all round it. Whenever practicable surface drainage and roof down pipes should be arranged to discharge into the pit's mouth, and during the dry season water should be poured down the pipe.

20. Surface earths, which are to be given in addition to deep earths in important cases, may consist of trenches 25 to 50 feet long, according to the dampness of the soil, 1 or 2 feet deep, filled with coke and ashes, and carried away from the building. The end of the metal conductor should be carried along the bottom and through the whole length of each trench.

21. The portion of the conductor between the building and earth connection may be in shallow horizontal trenches, surrounded on all sides by 6 inches of coke or charcoal.

22. Conductors should be fixed to the walls of buildings with small staples of the same metal as the conductors themselves.

23. Allowance must be made for contraction and expansion due to temperature by introduction of suitable bends and loops at intervals along the lengths of the conductors.

24. In erecting conductors unnecessary bends are to be avoided. All bends should be gradual, sharp re-entering angles are not admissible. Conductors should be taken through and not round small projections.

25. Conductors should be tested immediately after erection, and once a year at the end of the dry hot weather. This will be carried out by the Executive Engineer, or competent Subordinate, in the manner described in the "Code of Instructions for the guidance of Public Works Officers in the erection and testing of Lightning Conductors," published by the Government of India in 1883.

26. A record of such tests should be kept up in a book in each Executive Engineer's office, which should contain a description and plan of all important conductors in the Division. This record should be a tabular statement showing (*a*) state of soil when inspected; (*b*) date of inspection; (c) lightning rods, state of points and connections; (*d*) conductors, and condition; (*e*) earth, condition and amount of resistance in Ohms at each test.

Road Metalling.

1. Road metal will consist either of broken stone, kankar, laterite, or vitrified brick.

2. When stone is used, it must be hard, tough, and durable; no boulders weighing less than 4 seers must be used.

3. Sandstone shall not be used, unless when thoroughly indurated by the action of heat.

4. Kankar, laterite, or vitrified brick shall be as tough and heavy as can be procured in the locality. A dark blue fracture will generally indicate a good specimen of kankar.

5. Stone road metal shall be broken to such a size as will pass in any direction through a ring $1\frac{1}{2}$ inches in diameter.

6. When kankar or vitrified brick is used, each piece of the material must be capable of passing through a ring 2 inches in diameter in every direction. When laterite is used the ring may be increased to 4 inches in diameter.

7. The thickness of metal to be laid on new roads will be 9 inches, and a coat of metal for repairs, to be laid down every five years, will be 3 inches deep.

8. The surface of a road must always follow approximately in profile the curve of a semi-ellipse, the centre of which is 3 inches higher than the sides for a width of 12 feet, and for other widths in proportion.

9. The berms (or earthen margins on each side of a road) will be each 6 feet wide. They shall always be maintained to the full height of the upper surface of the metal on the outer edges of the road, and shall slope from this point outwards with an inclination of 1 in 10.

10. Road metal, before being laid on a road, must be perfectly clean and free from any admixture of earth or other foreign matter. In order to ensure this, it will generally be necessary to break and hand-pick the kankar, and the Executive Engineer's directions will be taken on this point.

11. When a road has to be repaired by laying a 3-inch coat over the old surface, the latter will first be scraped and made perfectly clean, and will afterwards be roughed with a pickaxe, and thoroughly soaked with water, before the new metal is laid.

12. To ensure that the upper surface of the road shall assume and retain the proper shape, as already described, wooden templates must be constantly used for testing the surface while the process of consolidation is going on.

13. The consolidation of the metal will be obtained by rolling or thorough ramming with iron rammers, weighing not less than 12 lbs., an abundance of water being used, and the ramming will be continued until the metal is so far consolidated, that light conveyances can pass over the new metal without making any mark or indentation in it.

14. Care must be taken that the incline or level in each length of the road is maintained perfectly true; and where the new metal terminates, no sudden step should be left, *but the junction of two surfaces must be made quite perfect.*

15. Metal for a new road, or for the repair of the surface of an old road, will be collected and stacked in a long continuous heap along the berm of the road. The stacks for a road 12 feet wide and a 3-inch renewal are to measure in cross section 4 feet wide at bottom, 2 feet at top, and 13 inches in height, and proportionate for other widths of roads or thickness of metal, but the height of the stack will always be 13 inches. The metal will never be paid for until these orders shall have been fully complied with, and until it shall have been inspected and measured by the Executive Engineer, or by such person as he may depute for this duty. Laterite metal should be stacked at least six months before it is to be consolidated.

16. The contractor shall use all due precaution for the safety of passengers by placing a barrier across each end of the length of road which is being worked upon.

17. This barrier must be substantial, and must in every case receive the approval of the Executive Engineer. At night a chowkidar (watchman) must be placed at each barrier to give due warning to persons using the road.

18. In the centre of the road, directly across it, and suspended 3 feet over it, will also be fixed a box 5 feet long and 1½ feet square, with transparent sides made of thin cloth facing up and down the road, and within this box will be placed two bright lights. The apparatus should be so arranged as to be seen at a distance of 100 yards along the road in both directions on a dark night.

19. No traffic will be permitted to pass over a road when under repairs, without the express permission of the Executive Engineer. If necessary, to meet the convenience of the public, only one-half of the width of a road will be repaired at a time.

20. No excavation for the supply of earth, to be used in the construction or repair of a road, shall be made nearer than 150 feet from its outer edge; unless the Executive Engineer shall give special directions in the matter.

21. **Stone metalling with steam roller.**—The metal having been collected and broken as already specified should be sifted through a screen consisting of vertical rods of iron placed 1½ inches apart before being

stacked. The screenings are to be deposited in heaps between the stack of metal and the road side drain.

22. In constructing new roads, no metal is to be laid down until the embankment or ground on which the metal is to be laid has been thoroughly consolidated and dressed to receive it, and the written permission of the officer in charge of the work has been received; in default of this the contractor will be responsible for all unequal settlements, or other defects of surface. In new roads the soling consisting of stones 6 inches thick, closely packed with their broadest sides horizontal, will then be laid and small interstices filled in with earth. The latter must on no account be allowed to cover the soling.

23. The road is then to be marked out to the proper width, and the metal laid with a slope of 1 in 24 from centre to sides of road. If it is to be 12 feet wide, the metal will be 6 inches deep in the centre and 3 inches at the sides, the convexity of the surface being preserved by templates placed at intervals of 10 feet, between which strings are stretched.

24. Only so much metal shall be spread on the road during the dry

31. Next morning commence rolling; until the rolling is completed, no more water is to be added, except at night, as if added during the same day the surface becomes too wet, and earth will stick to the roller and drag up pieces of metal.

32. When road is quite hard, spread another thin layer of dry earth over surface just enough to cover the stone. This must also be broken small and spread by hand by a line of coolies sitting across the road. Cover this with the metal screenings, water in the afternoon and roll next morning until hard.

33. Finally on roads inside the Cantonments, give ½-inch clean river sand over the whole surface of road as a top dressing; this may be rolled once.

34. If heavy rain falls work must be stopped until earth has dried again.

35. **General.**—The earthen sides of the road are to keep pace with the finished consolidation. If the berms are wide, they will be finished with a slope of 1 in 40 for a width of 14 feet on each side of the metal, and thence with an even slope to the sides drains; they are to be well rolled.

36. When earth is taken from the road side drains to make up the earthen sides, the levels of the drains are to be carefully preserved, and where not otherwise directed the sides are to be sloped off at an angle 45° and cut in a perfectly straight line.

37. In re-metalling existing roads, the surface of the old metal is to be scored across with a pick at intervals of 1½ feet, so as to give the new metal a hold on the old, and all ruts and hollows are to be filled up with broken metal before the fresh coat is laid; this is to be done and earthen sides finished as specified above.

38. At the termination of any coat of metal, the old and new coats are to be connected by a long ramp or slope which is not to be terminated with a feather edge, but is to be buried in the old coat.

39. After consolidation a stone metalled road will often work loose and break up; in this case it must be re-rolled with a little top dressing added, and it will then rarely give any more trouble. It should be kept watered for three weeks after consolidation is completed.

40. **Patch repairs.**—In executing repairs the hole, rut, or patch is to be cut out to the full depth of the coat of metal in a rectangular form enclosing the patch with sides parallel to the centre line of the road, the vertical edges being sloped off at an angle of 45°.

41. Road metal as specified above is then to be laid in the holes and

covered with a $\frac{1}{4}$-inch of earth and $\frac{1}{2}$ an inch of screenings, its surface being half its depth above the road. It is then to be consolidated with water and heavy iron hammers until the finished surface of the new patch lies perfectly even with the surface of the road.

Well-Sinking.

1. The method employed in sinking wells varies greatly in different places; the opinion of the local native well-sinkers should always be invited, as they are generally very expert in their profession.

2. The following specifications are given as general ones to be followed in the case of (1) hard soil, (2) sandy soil.

3. **Hard Soil.**—Rates will include all plant and labor requisite, except where casing is required, the planking for which will be supplied to the contractor who will find the labor for fixing it. The contractor is to provide secure means of descending into the well during the progress of the work.

4. The excavation for the well will be first marked out to the requisite diameter, which will be 2 feet larger than that of the outside of the steining.

5. The excavation will then be commenced and continued vertically downwards until the water level is reached, care being taken to keep it of the same diameter throughout. A shaft 4 feet in diameter will then be sunk to ascertain that a water-bearing stratum has been reached, which will give a permanent supply of at least 10 feet of water.

6. Should any sandy or shaly soil be met with, the sides of the excavation must be cased with planking. Rock must be carefully blasted out, the charges used being first approved by the officer in charge of the work.

7. The curb will then be placed at the bottom, and will consist of separate thicknesses of sound heart-wood of shisham, mulberry, or other hard wood cut to the requisite curve, dove-tailed, dowelled and fastened with bolts, straps and treenails as shown in the drawings. It will first be put together on the surface of the ground and after being examined by the officer in charge of the work, it will be taken to pieces, tarred, and lowered down to the bottom of the well, where it will be put together and firmly fixed and levelled.

8. Six 1-inch vertical iron rods rising above the curb as high as the depth of water proposed will then be passed through the centre of the curb at equal intervals, and be secured below with nuts to tie down the steining under the water to the curb. These tie-rods being secured so as to keep

them vertical, the building of the steining on the curb will be commenced round them.

9. The steining will be of brickwork or rubble masonry laid in mortar. If of brickwork it will be $1\frac{1}{2}$ feet thick, and of bricks specially moulded to the requisite curve and radius, and laid as specified for 1st class brickwork. Drawings of the bricks and bond to be observed will be supplied to the contractor. If in rubble masonry, the steining will be 2 feet thick; the stones must be roughly dressed with the hammer to the requisite shape, and the work executed otherwise as specified for coursed rubble masonry in mortar.

10. On the completion of a height of steining equal to the proposed depth of water, a circle of flat bar iron $3'' \times \frac{1}{2}''$ will be laid on top, through holes in which the iron tie-rods will pass and against which they will be tightly screwed up, the tops of the screws being rivetted on to the nuts. Weep-holes $6'' \times 3''$ are to be left at intervals in the steining as may be directed, for the admission of water.

11. The brickwork or masonry will then be allowed to stand until the mortar has set, when the sinking of the cylinder may be commenced, the permission of the officer in charge of the work having first been obtained. The earth below the water level will be excavated and the cylinder loaded, care being taken that it descends evenly and vertically.

12. When the requisite depth has been obtained the sinking is to cease and steining to be carried up to the top, the vacant space round the steining being filled in and thoroughly rammed as work proceeds. If it be intended to fix a platform or pump in the well, holes $1' \times 6''$, into the bottom of which 1-inch bolts are to be built, must be left in the steining at the requisite intervals, into which beams can be fixed.

13. The top portion of steining will be corbelled out to the outside to support the four brick pillars and the portion of the platform which rests over the filling and to prevent any settlement. The corbelling will commence 10 courses below the top and will project $2\frac{1}{2}$ inches in each course.

14. Round the well will be a platform about 6 feet wide with a brick or terrace floor laid with a slope to a drain round the outside of it, and having a curb round the inside to prevent water flowing back into the well.

15. All soil and rubbish must be removed from under the curb until the sole has an even surface, after which a wooden grating is to be fitted in the well, and filled up with broken stone to a height of 2 feet.

16. **Sandy Soil.**—In many localities in India the water-bearing sand

Clean out cracks with a brush, and having boiled the materials, apply with a small trowel.

(ii). 12 chittacks resin, 8 chittacks sulphur, 1 seer linseed oil.

Grind the resin and sulphur fine, mix together, put into the oil, and then boil the whole together.

(iii). To stop fine hair cracks in a new roof the following is often very successful :—

Spread over the roof a solution of 1 part cement, 1 part cow-dung, 1 part sand—it takes two days to set.

2. **Cleaning Marble.**—Mix together one part by weight of country soap with three parts of quicklime and sufficient water to form a paste. Lay on with a brush, and when dry, rub down with pumice stone.

3. **Putty.**—Take 1 seer whiting, 1 chittack white lead (dry), 6 chittacks raw linseed oil, 2½ tolahs litharge, mix well together and then beat with a wooden mallet until thoroughly incorporated. If the putty becomes hard it can be restored by heating it, and working it up again while hot.

4. **To soften putty.**—One lb. of American pearlash, 3 lbs. of quicklime ; slake the lime in water, then add the pearlash, and make the whole about the consistency of paint. Apply it to both sides of the glass, and let it remain for twelve hours, when the putty will be so softened that the glass may be easily taken out of the frame.

5. **Linseed oil.**—The choice of linseed oil is of peculiar consequence to the varnish maker, as upon its quality, to a great extent, depends the beauty and durability of the varnish. Oil expressed from green, unripe seed always abounds with watery, acidulous particles. The quality of the oil may be determined in the following manner :—Fill a phial with oil, and hold it up to the light ; if bad, it will appear opaque, turbid, and thick ; its taste is acid and bitter upon the tongue, and it smells rancid and strong ; this ought to be rejected. Oil from fine full-grown ripe seed, when viewed in a phial, will appear limpid, pale, and brilliant ; it is mellow and sweet to the taste, has very little smell, is specifically lighter than impure oil, and when boiled or clarified, dries quickly and firmly, and does not materially change the colour of the varnish when made, but appears limpid and brilliant.

6. **Asphalte varnish.**—Boil coal tar until it shows a disposition to harden on cooling ; this can be ascertained by rubbing a little on a piece of metal. Then add about 20 per cent. of lump-asphalte, stirring it

with the boiling coal tar until all the lumps are melted, when it can be allowed to cool, and kept for use. This makes a very bright varnish for sheet-metals, and is cheap and durable.

7. **Varnish for ironwork.**—Dissolve, in about 2 lbs. of tar-oil, $\frac{1}{2}$ lb. of asphaltum, and a like quantity of pounded resin, mix hot in an iron kettle, care being taken to prevent any contact with the flame. When cold, the varnish is ready for use. This varnish is for out-door wood and ironwork.

8. **Varnish for common work.**—This varnish is intended for protecting surfaces against atmospheric exposure. It has been used for coating wood and ironwork with great advantage. Take 3 lbs. of resin and powder it, place it in a tin can, and add $2\frac{1}{2}$ pints of spirits of turpentine, well shake and let it stand, occasionally shaking it for a day or two. Then add of boiled oil 5 quarts, well shake altogether, and allow it to stand in a warm room till clear. The clear portion is decanted and used, or reduced with spirits of turpentine until of the proper consistency.

9. **Varnish for iron patterns.**—A good varnish for iron is made as follows:—Take oil of turpentine, and drop into it, drop by drop, strong commercial oil of vitriol; the acid will cause a dark syrupy precipitate in the oil of turpentine; keep adding drops of vitriol until the precipitate shall have ceased, then pour out the liquid, and wash the syrupy mass with water, and it is ready for use. Heat the iron to be varnished to a gentle heat, apply the syrupy product, and allow it to dry.

10. **To remove old paint.**—Wet the place with naphtha, repeating as often as is required; but frequently one application will dissolve the paint. As soon as it is softened, rub the surface clean. Chloroform, mixed with a small quantity of spirit of ammonia, composed of strong ammoniac, has been employed very successfully to remove the stains of dry paint from wood and other substances.

11. **Rendering wood incombustible.**— Soak the wood in a strong solution of alum and sulphate of copper. About 1 lb. of alum and 1 lb. of sulphate of copper should be sufficient for 100 gallons of water. These substances are dissolved in a small quantity of hot water, then mixed with the water in the vessel in which the wood is to be steeped. The timber to be rendered fire-proof can be kept under the liquor by stones or any other mode of sinking it. All that is required is a water-tight vessel of sufficient dimension to hold enough of the liquor to cover the timbers which should be allowed to soak for about four or five days. After this, it is taken out

and allowed to dry thoroughly before being used. A plan of rendering the wood partially fire-proof is to whitewash it two or three times.

12. **Glue-melting.**—Break the glue into small pieces, and soak from twelve to twenty-four hours in cold water, put the glue in the glue-pot, fill the outer vessel with water, and apply heat. For ordinary purposes it should run freely, and be of the consistency of thin treacle. The hotter glue is, the more force it will exert in keeping the two parts glued together; in all large and long joints the glue should be applied immediately after boiling. Glue loses most of its strength by being often melted; that glue, therefore, which is newly made, is much preferable to that which has been used. When done with, add some of the boiling water from the outer vessel to the glue, so as to make it too thin for use. Put it away till wanted again, and by the time the water in the outer vessel is boiled, the glue in the inner is ready melted and the proper thickness for use. Powdered chalk, brick-dust, or saw-dust added to glue, will make it hold with more than ordinary firmness.

13. **Glue to resist heat or moisture.**—Mix a handful of quicklime in 4 ozs. of linseed oil; boil them to a good thickness, then spread it on tin plates in the shade, and it will become very hard, but may be easily dissolved over the fire as glue. A glue which will resist the action of water is made by boiling 1 lb. of common glue in 2 quarts of skimmed milk.

14. **Marine glue.**—Dissolve by heat one part of pure india-rubber in naphtha; when melted, add two parts shellac; melt until mixed.

15. **Good alloy for working models.**—4 parts copper, 1 tin, $\frac{1}{4}$ zinc. Hardness increased by doubling zinc.

16. **Brazing solder.**—Melt brass with $\frac{1}{6}$th its weight of zinc. Pour out of crucible, cool, and granulate by crushing under a hammer.

17. **Coloring walls of a Racquet court.**—Mix for one hundred square feet of walling—

Lamp black 10 chittacks; white lead 6 chittacks; linseed oil 12 chittacks; turpentine $1\frac{1}{4}$ chittacks.

This will lie dead without shine on most walls and will not come off on racquet balls or clothes.

18. **Printing Ferrotype plans.**—Put the tracing in the press and then the prepared paper over it. Shut the press and place it in the sunlight. Expose it for 2 minutes only. Then take the press into a dark room and remove the paper from the press and place it in a dish and pour

water over it carefully, so as not to leave any portion of the paper dry. Wait for 4 or 5 minutes, then again pour water on the paper and again wait. Continue this process until the lines stand out clearly, then take the paper from the dish and dry it. The press is a solid frame with a hinged glass lid.

Military Department No. 1681F. *of* 25*th June*, 1898.

APPENDIX C.

Specification of Wrought-iron work of Bridges, Trusses, &c.

1. **Materials.**—The wrought-iron is to be well and cleanly rolled to the full sections shown on the drawing or in the specification, and free from scales, blisters, laminations, cracked edges, and defects of every sort, and the name of the maker is to be rolled or stamped on every piece.

2. It must be of such strength and quality as to be equal to the following tensional strains, and to indicate the following percentages of contraction of the tested area at the point of fracture, and percentages of elongation :—

	Tensional stresses per square inch.	Percentage of contraction of fractured area.	Percentages of elongations in a length of 10 inches.
	Tons.		
Round and square bars and flat bars under 6 inches wide, ...	24	20	15
Angle, T, or other bars, and flat bars 6 inches wide and upwards, ...	22	15	12
Plates, ...	21	10	8
Plates across grain, ...	18	5	4

The rivet iron must be of such a quality that any rivet will stand the following tests without showing signs of failure :—

Bending double upon itself whilst cold.

Bending double upon itself whilst red hot.

The shank being nicked whilst cold and bent double, showing the fibre of the iron to be of good quality.

Flattening down the head whilst red hot until its diameter is equal to $2\frac{1}{2}$ times that of the shank, without showing any signs of cracking at the edges.

Punching through the shank when at a red heat, with a taper punch, a round hole the diameter of the rivet, without showing signs of cracking or splitting.

The tests are to be conducted at the works of the contractor or elsewhere, or both, as may be determined by the Inspecting officer. The expense of the tests is to be borne as provided for in the conditions of contract.

No material is to be used which, in the opinion of the Inspecting officer, falls short of the tests and other requirements of the specification, and no iron except of British or Indian manufacture is to be used throughout the contract.

Firms tendering are required to submit with their tenders the names of the manufacturers, and the market name of the iron they propose to use.

3. **Manufacture.**—It is to be expressly understood that the greatest accuracy is to be observed in every part of the work, a main object of the designs being to facilitate as much as possible the erection of the work by perfection of workmanship. All corresponding parts of all spans or trusses must be made exactly similar and interchangeable.

4. All plates and bars must be rolled to the full sections, and the angle, T, channel, or other bars to the full widths and weights per foot, shown on the drawings. All bars which do not hold their full widths and weights from end to end, or which have rough, jagged, or imperfect edges, or ends, will be rejected.

5. All plates, flat bars, and angle, T, channel, or other bars must be carefully levelled and straightened (the angle, T, channel, or other bars by pressure and not by hammering) before and after they are punched or drilled. All edges of all plates, and the ends of all angle-irons and bars, must be planed dead true to the dimensions, or, where planing is impossible, they must be dressed off fair with hammer, chisel, and file. No rough edges fresh from the shears will be permitted anywhere throughout the work.

6. All rivet holes to be filled in the field are to be *drilled.*

All other rivet holes may be either drilled or punched, at the option of the contractor, but any plate or bar in which the holes are not accurately in place will be rejected. The holes through which any one rivet passes must correspond in any number of plates or bars.

Although the word "rivets" may be used on the drawings, the rivet *holes* are to be made the sizes figured, and in no case must the diameter of the rivet be more than $\frac{1}{32}$-inch less than the diameter of the hole it has to fill. All loose rivets, and rivets with cracked, badly formed, or deficient heads, must be cut out and replaced by others. Rivets must also be cut out when required for the examination of the work. All work intended to be rivetted or bolted together must be absolutely in contact all over the whole surface.

All rivets, unless otherwise specified, are to be cup-headed at each end, and the heads are to contain not less than $1\frac{1}{4}$ diameters of the rivet.

Whenever necessary for the division of the work for transport, the rivets are to be left out, but the holes in all cases must be drilled ready for rivetting, and all the requisite rivets, including the spare rivets, must be sent with the ironwork.

7. In all cover plates, except in webs of plate girders, the fibre of the iron must run in the direction of the length of the span.

All plates must be shaped to the full sizes shown on the drawings, and any plate in which the rivet holes have been drilled nearer to the edge than shown on the drawings will be rejected.

Where cover plates are used to connect plates of different thicknesses, so much of the covers must be planed down as will make them fit fairly over the joint, no packing plates being allowed. The figured dimensions on the drawings show the different thicknesses after the cover plates have been planed down.

8. The main girders of all spans above 20 feet are to be built with a camber in the arc of a circle, the upper members being proportionately longer than the lower. The extent of the camber is in each case figured on the drawing.

The ends of all plates, &c., must be chipped and filed so as to butt with perfect accuracy over the whole of the meeting surfaces to the true radius necessary for the specified camber, and any joint which fails to form a perfect butt all over will involve the rejection of the length or lengths of the members which cannot be made to fit without being shortened.

Girders of 20 feet span and under are to be without camber.

9. The underside of the bearing plates of all main girders must be perfectly level and the rivets countersunk.

All bed plates are to be absolutely flat, and the guiding edges planed and truly parallel.

10. All bolts are to be screwed to Whitworth's standard thread, and all nuts must fit too tightly to be turned by hand. The heads and nuts for all timber bolts (except where otherwise shown on the drawings) and service bolts are to be square; for other bolts they are to be hexagonal.

The head and body of all bolts are to be forged out of one piece of rod or bar iron. All bolts are to be screwed for a length of three diameters.

11. **Completion of Work and Erection.**—All the spans are to be temporarily erected complete, so that accuracy of fit and perfection of workmanship may be assured.

As the work is erected, all the holes which are left to be rivetted in the field must be filled at one and the same time by temporary bolts, $\frac{1}{16}$-inch less in diameter than the holes which they fill, firmly screwed or keyed up. It will not be sufficient that bolts shall be placed in a certain number of holes only at a time, nor will it be sufficient that only such a number of bolts shall be inserted as may temporarily hold the span together.

12. **Painting, Marking, &c.**—The whole of the ironwork, with the exception of the bolts and rivets, is to be scraped perfectly free from rust, scales, and dirt, and then brushed all over with boiling hot linseed oil. It is afterwards to be painted with two coats of good oil paint, the first being of red lead and the second of Roman ochre, or other colours to be specially approved by the Inspecting officer. Wherever plates or bars are to be rivetted together, the surfaces that will be in contact are to be thoroughly cleaned immediately before plating, and one of them is to be covered with a good coat of red lead paint.

One end of every case is to be painted the same colour as the span for which its contents are intended.

The bolts (including the service bolts) and rivets are to be heated to the temperature of melted lead, and then dipped into boiled linseed oil.

13. Every portion of every span is to be very distinctly stencilled with paint and marked with the punch for guidance in erection, and every piece or bundle of iron is to be similarly marked, and every packing case branded, with such marks as the Inspecting officer may require.

All parts of the work are to be stamped with the letters "I. S. R." or such other letters as may be ordered.

A neat casting bearing the name of the manufacturer, with place and date of manufacture, is to be bolted conspicuously on every span of main girders, and on every truss.

Specification of Steel work for Bridges, Trusses, &c.

1. **Materials.**—The steel is to be well and cleanly rolled to the full sections shown on the drawings or named in the specification, and free from scales, blisters, laminations, cracked edges, and defects of every sort, and the name of the maker, and the distinguishing number of the plate or bar, are to be rolled or stamped on every piece. The names of the makers from whom it is proposed to obtain the steel, are to be submitted for approval to the Inspecting officer.

2. The steel must be of such strength and quality as to be equal to the following tensional stresses, and to indicate the following percentages of elongation :—

	Tensional stresses per square inch.	Percentages of elongation in a length of 10 inches.
	Tons.	
Steel in plates, either with or across the grain, and in angle or other bars, not less than	27	20
Or more than	31	
Steel rods for rivets and bolts not less than	25	25
Or more than	28	

3. Strips of steel, whether cut lengthwise or crosswise, of any plate or bar heated to a low cherry red, and cooled in water at a temperature of 82° Fahrenheit, must stand bending double round a curve of which the diameter is not more than three times the thickness of the piece tested. In addition to this, angle and other bars must stand the test known at Lloyd's as the ram's horn test.

4. All rivets and bolts are to be of steel, and the steel used for them must be ingot steel of a special quality, and the rivets and bolts must stand bending double, both hot and cold, and also flattening down from the head, without showing cracks or other defects.

Side and end shearings must be taken as samples from every plate and flat bar and from as many angle, T, channel, and other bars as the Inspecting officer shall require. At least 20 per cent. of the samples so

taken will be tested for tensile strength, and the whole of them for bending in the manner described above; but it is to be distinctly understood that power is reserved to test every plate and bar for tensile strength if the Inspecting officer thinks fit; also that such power will be exercised in the event of there being in his opinion any indication that the material supplied is not equal in every respect to the requirements or intentions of the specification. For this purpose each sample must bear a number stamped to the satisfaction of the Inspecting officer corresponding to the plate or bar from which it is taken, and all samples must be kept until the completion of the contract.

In addition to the above tests, samples of the steel supplied for use will be from time to time chemically examined; and should such examination show the presence of silicon, phosphorus, or sulphur to a greater extent than 0·06 per cent. of any one of them, no further supplies of steel will be accepted from the makers of the bad sample until the Inspecting officer is satisfied that in future supplies the percentages of silicon, phosphorus, and sulphur will be reduced so as not to exceed the maximum limit.

The above tests are to be conducted at the works of the contractor or elsewhere, or both as may be determined by the Inspecting officer. The expense of the tests and analysis is to be borne as provided for in the conditions of contract.

No plate or bar is to be annealed or otherwise manipulated after leaving the rolls without the special authority of the Inspecting officer and his approval of the process employed, and when annealing is permitted, the test pieces are not to be cut off till the annealing is completed.

No material is to be used which, in the opinion of the Inspecting officer, falls short of the tests and other requirements of the specification.

Firms tendering are required to submit with their tender the names of the makers from whom they propose to obtain the steel, and the character of the steel to be employed, *i.e.*, whether Bessemer acid or Open Hearth acid. The latter is preferred. Basic steel will not be accepted for girder or roof work. In the event of the acceptance of their tender, it will be upon the understanding that the steel will actually be obtained from such firms, unless written permission be given to the contrary.

5. **Manufacture.**—All plates and bars must be carefully levelled and straightened *(by pressure and not by hammering)* before and after they are punched or drilled. Every sheared edge, whether of a plate or bar, must have at least $\frac{1}{8}$th of an inch taken off it by machine or by the

chisel, and any plate or bar too small to leave $\frac{1}{8}$th of an inch for planing or chipping on every sheared edge will be rejected.

6. All holes are to be drilled, but the contractor may, if he think proper, first punch a smaller hole of such diameter in each case as to leave at least $\frac{1}{8}$th inch of material all round to be subsequently drilled out ; thus the *punched* hole intended to be enlarged to $\frac{3}{4}$-inch must not exceed at the largest end $\frac{1}{2}$-inch in diameter. When punched holes are thus drilled out, the punching must be so accurate that when the work is put together before drilling, a rivet, $\frac{1}{32}$-inch less in diameter than the size of the punched hole, can be easily passed through all the holes. All burrs left by the drill are to be completely removed. All punched holes are to be marked off with a centre punch, and punched with a nipple punch.

All rivetting is to be done by hydraulic, steam, or other machines of approved construction, and all rivet heads are to project through the holes before closing not less than $1\frac{5}{8}$ diameters for those closed at the works, and $1\frac{1}{2}$ diameters for those to be closed in the field, a further and sufficient allowance for filling the hole being also made when the rivet passes through more than two plates or bars.

Except when this specification differs from that for wrought-iron work the latter is to be followed.

General Specification for Cast-iron.

1. The cast-iron used is to be a mixture of soft grey iron. A proportion of scrap approved by the Inspecting officer may be used, and no pig iron except of British or Indian manufacture is to be used in any part of the contract. Firms tendering are required to submit with their tenders the names of the manufacturers and the market name of the pig iron which they propose to use.

2. The contractor must cast twice each day from the same metal from which the articles are cast *(a)* two bars $2'' \times 1'' \times 3'\ 6''$ long, cast with the broader side uppermost, and *(b)* two bars exactly 1 inch square in the middle for a length of $1\frac{1}{2}$ inches, with ends of suitable shape for holding in a testing machine.

One of the bars *(a)* must be tested on edge on bearings 3 feet apart, and it must bear a weight of 30 cwt. in the centre without breaking, and must give a deflection of at least 0·3 inch. One of the bars *(b)* is to be tested in a suitable machine, to be approved by the Inspecting officer, to

for either sleepers or chairs, the inclination of the rail must not vary from that prescribed by more than $\frac{1}{2}$ per cent., that is if the prescribed inclination be 1 in 20, or 5 per cent., it must not be less than $4\frac{1}{2}$ nor exceed $5\frac{1}{2}$ per cent. In the case of pipes or columns, the core must not at any part exceed $\frac{1}{16}$th of an inch out of centre.

8. Cast-iron sleepers or chairs will be subjected to a drop test as follows. A piece of rail, 18 inches long, is to be keyed up in the sleeper or chair, the chair will be secured to a sleeper, 8 feet long, 10 inches wide and 5 inches deep, of either teak, sál, or deodar; the cast-iron sleeper, or the timber sleeper and chair, with the rail fixed in it, will then be laid on a bed of sand, 2 feet thick, supporting the sleeper evenly all over, and laid on a cast-iron bed plate, 8 inches thick. When in position the rail will be struck by a monkey weighing 420 lbs. falling from a height commencing at 2 feet and rising by successive increments of 1 foot up to 7 feet, and whenever any chair or sleeper does not bear these blows without cracking or showing other signs of failure, all the sleepers or chairs cast on the same day will be rejected.

When not less than one per cent. of the total number are tested in this manner, the test prescribed in paragraph 2 may be dispensed with.

Pipes or columns are to be tested up to a pressure of 200 lbs. per square inch, and whilst under pressure are to be thoroughly sounded with a hammer suitably proportioned to their strength, and should any leakage occur they will be rejected.

When pipes have turned and bored or faced joints, a few lengths are to be put together and tested under the above pressure.

PART II.

WATER-SUPPLY.

WATER-SUPPLY.

1. **General remarks or preliminary arrangements.**—Water is laid on to Indian Cantonments in one of the following ways :—

(*a*). The Cantonment has a share of the adjacent Municipal supply, sometimes being a partner in the same, at others merely paying a water-rate for the quantity consumed.

(*b*). The Cantonment has its own supply quite separate from the Municipality.

(*c*). The Cantonment has its own supply in which, however, the Municipality has a share, sometimes as a partner, at others by paying a water-rate.

2. The agreement between the Cantonment and Municipality always involves a lengthy discussion, and is finally ratified with the sanction of

e of supply in the plains
in the bed of a river or
generally pumped from
antonment distribution
pply is taken by gravity
it is pumped into the
of any kind is required.
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into trial wells sunk at
the driest time of the
the lowest known level
uisite number of wells
enerally in one or two
little that is authentic

is known about the yield of wells in different soils. Experience has, however, shown that under the steady drain caused by the supply on the under-ground basin forming its source, the water level at the head-works gradually falls, and the supply eventually obtained is far short of that

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Engineer" and
"Division."

anticipated, from the results of the experiments originally made to ascertain the inflow at the wells. For instance after the Umballa City Works had been working for six months, it was found that the actual yield was only 195 gallons per minute instead of 300 gallons as expected, showing a falling off of $\frac{1}{3}$rd in a few months.

It is evident, therefore, that the probable permanent yield of wells forming the head-works must always be a subject for prolonged and anxious consideration, as on its correct solution the success of the supply will mainly depend.

6. **Springs in hills.**—In the hills this difficulty is of much less importance. The supply from springs is fairly uniform year by year.

Here the chief cause of anxiety is the lowness of the springs during the hottest and driest time of the year before the rains break, when the station is usually at its fullest; another trouble is the tendency of hill stations to gradually extend, thus rendering it necessary to take in more springs at the head. The state of the supply at the driest season of the driest year and the power of gradually increasing it, if necessary, are therefore the chief points to be considered in deciding on the yield of a hill water-supply.

7. The supply from a spring in a hill station should be collected, if possible, at the point where it leaves the hillside, or as near this point as convenient, in a small masonry tank, a design for which is shown in *Plate* LXXXI.

8. Besides the yield, the purity of the water has to be ascertained before further action can be taken. This is done by both chemical and bacteriological examination. Rules for collecting water for this examination are given at the end of this chapter, *see* pages 86 and 87.

9. **Mains.**—The mains of a water-supply should be of cast-iron coated with Dr. Angus Smith's composition; the masonry conduits of old supply systems are never likely to be repeated. No cast-iron pipe of less than 3 inches in diameter should be used, all smaller pipes should be galvanised wrought-iron. Turned and bored pipes are preferable when the pipe line is straight, and the ground admits of it, because they are cheaper and easier to lay. Where these pipes are used, local conditions will determine the proportion of pipes required with the ordinary wide socket for lead joints. In mains it is usually 20 per cent. rising to 35 per cent. in distribution systems with numerous connections, winding streets, &c. In the hills where sharp curves are frequent, spigot and socket pipes are almost essential,

When pipes are 9 inches in diameter and upwards, wrought-iron rings shrunk on to the spigot ends of both plain and turned and bored pipes tend greatly to preserve them from breakage during transit. In laying plain pipes, these rings can be retained in position.

10. **Filters.**—In hill supplies filtration is rarely necessary, but it is frequently required in the plains. The Pasteur system of filters is now being experimented on in some places in India, but its success in Cantonments seems very uncertain. The following is the system of filtration adopted at Calcutta where the water is pumped from the Hooghly above Barrackpore direct into the filter beds :—

(*a*). The first or lowest layer of filtering material deposited on the bottom of the filter consists of a layer of well-washed, clean gravel or shingle, of the uniform size of nuts or beans ; this layer is 6 inches thick at centre and 3 inches thick at sides of tank, its surface being carefully raked to a regular incline.

(*b*). The second layer consists of well-washed, clean gravel or shingle, of the uniform size of peas to be in a like manner deposited to a depth of 6 inches at the centre, and 3 inches at the side of filter.

(*c*). The third layer is composed of well-washed, clean, medium-sized sand, intermixed with an equal bulk of clean and well-washed shells ; the thickness of this composite layer to be uniformly 9 inches over the whole filter bed.

(*d*). The fourth layer is 10 inches thick, and consists of well-washed sand.

(*e*). The fifth and top layer consists of a layer of clean and well-washed sand 12 inches thick, laid perfectly smooth and level.

11. **Rate of filtration.**—The rate of filtration should be regulated to half a cubic foot per hour per square foot of filtering surface ; with a filtering bed about 5 feet thick this is obtained with a head of 1 to 3 feet depending on the state of freshness of the filtering material.

12. **Reservoirs.**—Reservoirs may be of masonry or of iron or steel. The former are liable to crack and be damaged by earthquakes, the latter to rust. The kind to be adopted must be decided by balancing the relative cost and liability to damage in each case, but circular iron or steel tanks are very convenient reservoirs when not too costly.

13. Both pumping and storage reservoirs should be divided into at

least two compartments of nearly equal size, to enable them to be cleaned and repaired periodically without unduly interfering with the supply. The neglect of this very obvious precaution has, in some supplies, caused great inconvenience and waste of water.

14. **Pumping machinery.**—The pumping machinery should be of sufficient size to deliver the whole supply in eight hours at the ordinary rate of working; all engines, boilers, &c., should be in duplicate so that one set of machinery can be always at work whilst the other is being cleaned or under repair.

The Worthington type of pumping machinery is now largely used for installations where the suction lift is small. For pumping from deep wells a Beam engine is usually employed. Direct acting engines are, however, cheaper all round, require smaller buildings, and need fewer repairs and less attention than the rotary engines.

For purposes of estimating, the cost of the pumping machinery may be taken at £50 per horse-power.

15. **Stand-posts.**—Under orders of Director-General Military Works, No. 2372B of 2nd August, 1894, the stand-posts manufactured by the Glenfield Co. of Kilmarnock are to be estimated for in preparing water-supply schemes. Each stand-post should be provided with a sluice valve, which must be fixed near the stand-post. Stand-posts should be built on a masonry platform about 9 feet long by 7 feet wide, if space permits; a mussack or ghurrah stands of suitable pattern should be provided under the tap. The platform should have a good slope to carry all wastage into a convenient drain.

16. **Drainage.**—No water-supply system is complete without an efficient drainage scheme; provision should be made for spillage, &c., from stand-posts being carried off by road side drains. Scour pipes should preferably be carried into some large main drain. Drains from stand-posts are often carried into gardens, but this system is not recommended as it often leads to a great waste of water.

17. **Indents Home and Projects.**—The metal materials for water supplies are demanded from the Secretary of State for India. Printed instructions for guidance in the preparation of indents were circulated with Director-General Military Works, No. 1409B., dated 8th May, 1897.

These instructions give great assistance regarding details of fitting, &c. In preparing indents it is desirable to ask for all specials, valves, stand-posts, and fittings, &c., to be supplied with the earliest shipment of the

pipes. In hill supplies, before these indents can be prepared, it is necessary to have an accurate survey of the pipe line, showing all bends, &c. This should be got out on a scale of 20 feet to 1 inch. To enable this to be done it is generally necessary to cut out the path for the pipe line along the hillside. This work usually forms a preliminary project.

18. **Calculations.**—The formulæ and tables to be used in calculations for water-supply systems are given on pages 97–98 under the heading "Calculations."

19. **Preliminary preparations.**—In beginning to lay an extensive length of main pipes, considerable delay, and consequent loss, is often experienced owing to a want of foresight in providing beforehand the necessary men, tools, and material required. The following is an enumeration of what it is necessary to provide, varying according to the peculiarities of the District and the extent of the work to be done:—

One or two skilled pipe-layers.
A number of labourers provided with picks, shovels, and phowrahs.
A night watchman.
A supply of picks, pick-handles, and wedges to replace broken ones.
A shear-legs or tripod, if the mains are of large diameter.
Blocks, tackle, and ropes or chain and slings.
Eight hand spikes for moving the pipes.
Four pieces of 3- or 4-inch piping for rolling the pipes in the trench.
Four long iron bars and two short ones.
Red and white lead paint: if turned and bored joints, cotton-waste and cleaning material.
A supply of spun yarn and pig lead.
Two oak blocks, strengthened with hoops to lay against the pipe sockets when driving.
Wooden plugs for the various sizes of pipes.
A lead pot and two ladles.
Chisels and caulking tools.
A small pair of bellows.
Two large hammers and three small ones.
Stock and dies, gas thread, for screwing branches.
Portable bench with vice.
Tube vice and tongs of sizes.
Tube cutters of sizes with spare cutting wheels.
Spirit level and a 12-foot straight-edge.

Two, or more, lanterns for lighting the trench at night.

A supply of rammers.

Some trestles or bamboos for guarding the open trench at night time or on the road crossings.

Planks and small pieces of timber for shoring the trench or for covering portions temporarily.

20. The centre line of every trench will be marked out by the Executive Engineer, or one of his assistants, and the contractor must carefully conform thereto in its excavation. In wet porous soil, and where the excavations are deeper than 7 feet, the sides of the trench must be properly shored up. The alignment of pipe trenches must be kept as straight and regular as possible.

21. On arrival at site, the pipes are to be "lined up" as near as circumstances permit to the alignment of trench they are to occupy. The pipes are to be unloaded from the carts with ends touching, sockets in all cases facing the direction from which the water will eventually flow, every twentieth pipe being duplicated to allow for joints, &c. At road crossings, &c., the number of pipes required will be ranged conveniently, half on either side of the space to be crossed. In the case of pipes less than 4 inches diameter they may be placed at suitable intervals in small stacks of not more than 25 pipes.

22. **Excavation of trench.**—The bed of the trench will be evenly and truly dressed throughout from change of grade to change of grade, to obviate any subsequent rectification, by packing or filling under the pipe. The "spoil" should be thrown out on the side of the trench opposite to that on which the pipes have been collected, and when road metal has to be removed and replaced, it should be separately deposited on one side of the trench, ready for subsequent re-use. All road crossings to be excavated half at a time, the second half being commenced after the first has been refilled over pipes laid, and opened for traffic.

23. In cases where blasting is necessary, the rock should be removed to a depth of at least 6 inches below formation level, and the bed of the trench made up with sand or thoroughly rammed earth before pipes are laid. In light or loamy soil the bottoms of trenches are to be well rammed before pipe-laying is commenced. Any holes or unsound places met with during excavation are to be carefully cut out and refilled with sand or well consolidated soil before pipes are laid.

24. In crossing marshy sites the grade can be preserved by sinking

slabs of stone or slate vertically through the soft soil (if of no great depth) to a firm foundation and adjusting their tops as required, *a concave notch forming a seat for the pipe.*

25. The minimum depth of trenches is to be 2 feet 6 inches plus the diameter of the pipe to be laid ; the minimum widths at top being as under :—

For pipes	3 to 6	inches—trench	18	inches	wide.
,, ,,	7 to 10	,, ,,	24	,,	,,
,, ,,	12 to 20	,, ,,	36	,,	,,

26. Local conditions will in all cases determine the best relative rates of progress of excavating and pipe-laying gangs ; as a general rule it should be sufficient for the former to keep from one to two full day's work ahead of the latter.

27. When a trench is left open at night a chowkidar must be left in charge, and a good oil lamp in a clean lantern, preferably furnished with red panes, must be placed at each end and also at intervals of 50 feet along the trench. If necessary a bamboo fence must be put up to prevent danger to passengers.

28. The bottom of the trench should be carefully graded, grade pegs spaced 50 to 200 feet apart being placed along the pipe line clear of the edge of the trench, with distinguishing marks at every point where the grade changes. The bottom of the trench will then be graded to a fixed vertical distance below these pegs by means of pieces of bamboo, of length equal to this distance, and boning rods, which are given to coolies and mates respectively. The grading of the bottom of trenches must be carefully checked by the officer in charge of the work before pipe-laying is commenced.

29. **Pipe-laying in general.**—All pipes are to be laid with sockets facing the direction from which water is to flow. Every pipe must be carefully sounded and examined before laying, for cracks or flaws that may so far have escaped detection. Each pipe must then be cleaned internally, for which purpose old sacking firmly bound to the end of a long bamboo to form a mop may be used. Pipes of small diameter should be up-ended, and all dust, &c., shaken out after the mop has been used.

30. Cracked pipes are to be cut with diamond pointed steel chisels, the cut to be made at least 6 inches beyond the visible extremity of the crack and on a line girdling the pipe at right angles to its longitudinal axis.

31. Work should generally be commenced at the extremity of the line furthest from the source of supply, or from a valve, branch, or special, forming a break in the line, and in the case of leading distribution mains, from the absolute end if possible. This procedure lessens the number of subsequent connections, saves collars, and obviates unnecessary cutting of pipes.

32. Lead required for jointing should always be supplied departmentally, otherwise, as it is an expensive item, contractors will starve the joints. It can be obtained from the arsenals, the lead of the snider bullet being very suitable. That of the modern bullet is too hard ; it can, however, be satisfactorily blended with blue virgin lead in any proportion found most desirable on trial. Lead from Commissariat tea-chests can sometimes be obtained, it is very soft.

33. The open end of the last pipe laid is to be securely closed on ceasing work for the day with a strong wooden plug fitting the socket of the pipe, around which it is securely fastened with a chain attachment and padlock.

34. **Pipes in use.**—The pipes in general use are :—

(*a*). Cast-iron pipes plain, spigot and socket.

(*b*). Cast-iron pipes turned and bored.

(*c*). Galvanised wrought-iron pipes with screw and socket joints, steam and water quality.

(*d*). Mild steel pipes for very great heads.

Cast-iron pipes are not very satisfactory for anything over 250 feet head, for although the market pipe is usually tested to 300 feet, it is difficult to make a lead joint to work under this head.

The galvanised wrought-iron pipes supplied through the Secretary of State are of such excellent quality that up to 2 inches in diameter they work safely under a head of 1,000 feet. Those supplied by Indian Firms can only be relied on for heads under 300 feet.

Special galvanised wrought-iron pipes up to 4 inches diameter capable of working safely under a head of 800 feet are easily obtainable from England on indent.

35. **Laying cast-iron pipes with plain, spigot and socket joints.**—The trench will be filled with a little soft earth free from stones, which will be shovelled in gradually, one heap being placed at the centre of each pipe. On these heaps the pipes are balanced, and they can then be easily graded and lined by scraping the earth away either by hand

or with shovels. For lowering the pipes into ordinary trenches ropes are necessary for 7-inch to 20-inch diameters; for larger sizes tackle is required.

36. The spigot end of the pipe to be jointed is first truly centered in its socket, steel wedges being used for this purpose. The socket is then caulked with white spun yarn or gasket, of which sufficient laps must be given to leave, after the yarn has been evenly and solidly packed to the shoulder of the socket with the yarning iron, the correct depth specified for the lead, from the face of the socket. This depth is to be—

For pipes	$2\frac{1}{2}$ to 4 inch,	...	...	...	1 inch.
" "	5 to 8 "	...	...	...	$1\frac{1}{4}$ "
" "	9 to 12 "	...	...	...	$1\frac{1}{2}$ "
" "	14 to 18 "	...	...	...	$1\frac{3}{4}$ "
" "	20 to 24 "	...	...	...	2 "

The laps of yarn used, which will never be less than three, must be all rather longer than the circumference of the socket, no make-up pieces are to be allowed. The laps are to be twisted into a rope of uniform thickness, and caulked in that form into the socket.

37. The pipes are then to be again carefully graded and the slope of each pipe tested with a hand level. The pipes which are now ready for leading are each supported in the centre for about two-thirds of their length on a flattened mound of earth, while at each joint is a small pit which is required for leading and caulking.

38. To lead the joints, first clear them of earth and pebbles. Then make a wrapper of spun yarn worked up with clay having the consistency of putty. This should be about 3 inches wide and $\frac{3}{4}$-inch thick and 4 inches longer than the diameter of the joint. Wrap this round the joint with the overlap on top, and make a hole in it to admit of the molten lead being poured in. This must be thoroughly liquid, and the ladle for pouring it into the joint should hold a little more than is required for one joint. The filling should be one operation and the lead should be poured in quickly. Then strip the wrapper off and use it in the next joint and so on.

39. When a section of a few hundred feet is leaded, the caulking should be put in hand. Each gang of caulkers should consist of at least four blacksmiths, and for large diameters the numbers should be increased. One of these must be a good smith. Place the men in line, the worst man in front, and let them proceed to caulk a joint each with a caulking iron

and blacksmith's hammer. Every 15 minutes move the gang on one joint, thus each joint receives an hour's caulking, and is worked on by all four smiths. The lower portion of the joint requires especial attention and supervision.

40. Should it be necessary to work quickly, many sections can be laid at the same time. Where their ends meet they may be joined by a sleeve joint, or by simply cutting the final pipe to length, when the spigot may be slipped into its socket by lifting one or two of the pipes laid kucha, on either side of the last joint to be laid.

41. **Laying cast-iron pipes with turned and bored joints.**— The first layer of soft earth should be completely filled in and rammed in stony rocky soil before placing the pipes in the trench, which must be quite free from windings. The turned fillet at spigot end and surface of the turned ring within the socket of each pipe are to be thoroughly cleaned and polished. This can be satisfactorily done by coolies using soft brick, sand, old sacking, and buckets of water. The surfaces so polished are then to be thoroughly washed, and the spigot end and socket ring are again wiped round with a clean wet cloth at the moment of inserting the former into the latter.

42. After the first pipe has been placed in position, the second is lowered and the spigot is carefully guided into the socket of the first by the ganger in the trench, who at the same time adjusts the pipe as regards alignment and grade. The next pipe is then brought up and used as a ram,* to drive the preceding pipe home, being swung on a rope sling by coolies, standing in equal rows on either side of the trench. These men lean forward head to shoulder and lift and swing together. The ram is guided by a second man in the trench who grasps the socket end, and assists in keeping the pipe straight and so delivering the blows fairly and evenly. The ganger meanwhile sits astride the last socket and closely watches and directs the driving home of the spigot therein.

This operation must be carried out with great care, particularly with pipes of small calibre, the sockets of which are apt to split if the driving home be over done, about four or five blows of the ram are generally sufficient for pipes up to 10 inches diameter. For those from 10 to 20 inches (beyond which T and B pipes are now rarely used) a pipe of 10 to 12 inches diameter makes an efficient ram. The use of a wooden buffer to

* The ram is sometimes used by hauling a pipe backwards and forwards on rollers laid upon the trench bottom. It is found, however, that progress is less by 30 per cent. than with a swinging ram.

deaden the blow is generally advocated. These blocks break up rapidly and with skilled pipe-layers they are not necessary.

43. No external joint of any kind whatsoever will be given to turned and bored pipes, but at points difficult of subsequent access, such as under railways, drains, &c., the joints should be leaded as an additional precaution.

44. In laying long lengths of turned and bored mains, lead joints should be given at intervals of about 100 yards, to allow for expansion and contraction. If plain pipes be not available, a turned spigot may be cut off at each point for this purpose. The laying of turned and bored pipes reversely, *i.e.*, driving sockets on to spigots is prohibited.

45. **Laying galvanised wrought-iron pipes with screw and socket joints.**—All piping when below ground will be laid at a minimum depth of 18 inches below the surface. All screwed connections to be taper-threaded, and the use of red or white lead, or any composition of any kind whatsoever in making joints is to be discouraged. No undulations are permitted, the piping must be truly laid to a grade either rising or falling, or dead level as may be ordered. In fixing tees, branches, &c., care must be taken that on no account is a branch pipe permitted to encroach, by projecting upon the waterway of the pipe from which it springs.

46. In ordinary pipe lines hardly any bends are required, and the pipe trench should be cut winding throughout except in cases where quick bends are required. The pipes when laid spring into quite sharp curves without any damage, and a good 14-foot steam-quality pipe can be bent in its length by means of crowbars to take a change of direction of 45°. This should not be attempted at joints or screw threads may part.

47. The joint is made by screwing the end of the pipe to be laid into the socket of the pipe last laid. To do this use four pipe tongs, two on each pipe worked in opposite directions: care must be taken to prevent the pipe already laid turning during the operation or tee pipes will get out of level. The end of the pipe last laid is supported above ground by a crowbar laid across the trench, thus facilitating the use of the tongs.

48. In the hills the pipes should be laid winding in the trench to allow for contraction when the cold water is run in. For the same reason the pipe on the inside of a curve should not bear against the rock side of the trench.

49. Sections of piping may be joined by a screw collar or coupling, which is run up the end of one pipe, and on the other being brought opposite, down the end of this pipe until it grasps both equally.

50. When the piping is more than 2 inches in diameter it cannot be bent to any great extent and it must be laid in the bottom of the trench.

51. **Laying mild steel pipes.**—For great heads and large diameters mild steel tubes are used. They are lap-welded and have special joints.

At Murree, steel rings carefully turned, were shrunk on to the ends of the pipes, one end being tongued and the other grooved. A rubber washer was placed in the groove and the tongue of the next pipe was then fitted into it, and heavy cast-iron collars fixed behind the steel rings. The joint was then secured by screwing up six cross bolts passing through holes in the cast-iron collars.

52. To provide for contraction and expansion, sleeves made from locomotive buffer tubes were placed over the ends of tubes after the steel rings had been removed. A deep lead filling was run in and caulked. To prevent this blowing out, segments of steel were placed round the tubes, bearing against the lead at the ends of the sleeve. Over these segments the ordinary cast-iron collars were placed and drawn together by the longitudinal bolts until the segments pressed firmly against the lead at either end of the sleeve. This joint worked well under a head of 1,400 feet. The idea was that contraction and expansion took place by the steel tubes sliding in the lead jackets.

53. **Testing and filling in—General.**—When the joints have been completed turn on the water and test them. This may be done by closing cross sluice valves and thus producing rams. This should be continued in each section for two days. Any leaking joints should be made good by leading and extra caulking.

54. After the pipes have been tested, the trenches are to be filled in with earth laid in 6-inch layers watered and carefully rammed, preferably with wooden rammers. Street metalling is to be restored and the surface neatly dressed to a proper level. All extra earth and rubbish to be removed forthwith by the contractor on the completion of the filling in of each trench. Great care must be taken that the space underneath the pipes is properly filled in and that the sockets are adequately supported. Any sinkage from defective laying within three months of completion will be made good by the contractor at his own expense.

55. **Joints in flanged pipes.**—In laying these, the faces of flanges or raised strips as the case may be must be first thoroughly cleaned, and in bolting up after the specified "insertion" has been placed in position, care

must be taken to tighten the flange bolts gradually and evenly all round. When washers of rubber or other material are used, they must be held in position by loops of thin twine through the bolt holes before the flanges are brought together, care being taken that the washer is not allowed to encroach in the least on the bore of the pipe. Chalk rubbed upon the faced strips of a flanged joint before inserting the washer facilitates subsequent removal, by preventing the latter from adhering to the metal faces. Leaks through bolt holes of flanged joints can be stopped by the insertion of lead washers under the head or nut of bolt, as may be required.

56. **Setting of valves.**—The covers and glands of all valves are to be removed, packing adjusted, spindles and gates examined, and the whole refitted in free and perfect order, before being sent to site. In setting, the valve must be carefully adjusted as nearly vertical as possible in both directions, before the lead joints of the connecting tail pieces are made. The specification already given for flanged joints applies equally to those of all valves.

57. **Surface boxes over valves.**—The top of the surface box should as a rule be flush with the roadway. Cast-iron surface boxes of the ordinary small conical type will be fixed as follows:—The trench filling is first thoroughly consolidated up to the level of the lower flange of the valve cover, and upon this is built a small encircling half brick dry wall, upon which rests the base of the surface box, the depth of the brickwork being such as to bring the top of the surface box level with the roadway. The packing and consolidation of the road metal round the box completes the operation. In the case of large valves on mains, to which access is considered desirable, pits constructed of pucka masonry with cast-iron flap covers will be necessary. These pits should be sufficiently large to enable a man to work round the valve.

58. **Distribution system.**—For the distribution system within station limits where the mains, especially in the plains, generally follow well graded roads, it will be unnecessary in most cases to do more than lay the pipes in trenches of uniform depth, in accordance with those grades, taking care to insert an air valve at every summit where there is no stand-post to act as such. Every case of doubt or difficulty that presents itself will be settled on the spot with the level as work proceeds, and the grades of each day's work are to be checked with the spirit level before the trenches are filled in.

59. It is very necessary that as pipes, &c., are laid, their exact posi-

tions should be clearly shown weekly on the record plans. The absence of such plans in the older supply systems has led to great inconvenience at times.

60. The following Table gives the weight of lead required for jointing cast-iron mains, on the assumption that up to 8 inches diameter the lead is $\frac{3}{8}$-inch thick, and beyond that $\frac{1}{2}$-inch thick. When however the reduced depths, specified in para. 36, which are sufficient up to heads of 300 feet, are used, the weights will be proportionately less.

Diameter of the pipe in inches.	Weight of lead in pounds.	Depth of lead in inches.	Diameter of the pipe in inches.	Weight of lead in pounds.	Depth of lead in inches.
$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{3}{8}$	11	$16\frac{1}{2}$	$2\frac{1}{4}$
2	$1\frac{3}{4}$	$1\frac{1}{2}$	12	$18\frac{1}{4}$	$2\frac{3}{8}$
$2\frac{1}{2}$	$2\frac{1}{4}$	$1\frac{5}{8}$	13	21	$2\frac{3}{8}$
3	$2\frac{3}{4}$	$1\frac{5}{8}$	14	$23\frac{1}{2}$	$2\frac{3}{8}$
4	4	$1\frac{3}{4}$	15	26	$2\frac{1}{2}$
5	$5\frac{1}{2}$	$1\frac{7}{8}$	16	$28\frac{1}{2}$	$2\frac{1}{2}$
6	7	2	17	31	$2\frac{1}{2}$
7	$8\frac{3}{4}$	2	18	$32\frac{1}{2}$	$2\frac{5}{8}$
8	$10\frac{1}{2}$	$2\frac{1}{8}$	19	34	$2\frac{5}{8}$
9	$12\frac{1}{2}$	$2\frac{1}{8}$	20	$35\frac{1}{2}$	$2\frac{5}{8}$
10	$14\frac{1}{2}$	$2\frac{1}{4}$	24	48	3

61. **Dr. Angus Smith's Solution and method of applying it to pipes**—It is anything but easy to put on this solution at site of work, but as it may have to be done at times, a description of the process to be followed is given below. The solution is an admixture of pitch and linseed oil. The pitch is made from coal tar distilled until the naphtha is entirely removed and the material deodorised and until the pitch is of the consistency of wax, 5 or 6 per cent. of linseed oil may then be added. Pitch which becomes hard and brittle when cold will not answer for this purpose.

62. Every pipe must be thoroughly dressed and freed from the sand which clings to the iron in the moulds, hard brushes being used in finishing to remove the loose dust. All rust must also be removed. If the pipe cannot be dipped directly after being cleaned the surface must be oiled with linseed oil to preserve it, until it is ready to be coated. No pipe is to be dipped after rust has set in.

63. Pitch of the proper quality having been obtained, it must be carefully heated in a suitable vessel to a temperature of [illegible] Fahrenheit, and must be maintained at not less than this temperature during the time of

dipping. The material will thicken and deteriorate after a number of pipes have been dipped, fresh pitch must therefore frequently be added, and occasionally the vessel must be entirely emptied of its old contents and refilled with fresh ingredients. The refuse will be hard and brittle, like common pitch.

64. Every pipe must attain a temperature of 300° Fahrenheit before removal from the pan. When this temperature is reached it may then be slowly taken out and laid upon skids to dry.

65. When coating turned and bored pipes the machined portions are coated with loam intermixed with water to form a paste which is allowed to dry before immersion, the loam breaks off when the pipe is cold.

66. **Cost of water in different supplies.**—The following Table gives the cost of water per thousand gallons as supplied to different Indian Cantonments where water-supply systems have been completed :—

Station.	Cost of				Total cost.
	Interest on Capital and depreciation.	Rate paid to Municipality.	Pumping expenses.	Other working expenses.	
	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.
Murree, ...	1 0 6	...	...	0 5 3	1 5 9
Rawal Pindi, ...	0 5 7	...	0 1 2	0 0 7	0 7 4
Dalhousie, ...	0 7 3	...	...	0 1 0	0 8 3
Chakrata, ...	1 12 11	...	...	0 2 1	1 15 0*
Agra, ...	0 2 0	0 4 6	...	0 0 7	0 7 1
Lucknow, ...	...	0 4 6	...	0 0 9	...
Allahabad, ...	0 4 2	0 4 0	...	0 0 6	0 8 8
Fort William, ...	0 3 3	1 0 0	...	0 1 0	1 4 3
Lebong, ...	0 15 0	0 6 0	...	0 2 7	1 7 7
Jubbulpore, ...	0 0 2	0 2 10	...	0 0 3	0 3 3
Quetta, ...	0 1 7	...	...	0 0 4	0 1 11
Karachi, ...	0 1 3	0 3 9	...	0 0 5	0 5 5
Mhow, ...	...	...	...	...	...
Sikandarabad, ...	...	0 1 3	...	...	...

67. The cost of maintenance varies considerably in different stations depending on :—

(*a*). Cost of fuel.
(*b*). Cost of labour and materials.
(*c*). Length of line and number of taps.
(*d*). The construction and position of reservoirs.
(*e*). The age and description of the machinery.

* The main is laid for 150,000 gallons per diem, but only 25,000 gallons are used at present.

68. For a period of two years after completion the whole line of main should be carefully patrolled daily by chowkidars, and any subsidence of the ground, signs of leakage, &c., at once reported; after this period the main lines need not be inspected more than once a week. The whole area supplied by water should be divided into convenient divisions, each division being placed in charge of a chowkidar or "Inspector." This man's duties are—

To inspect every tap and line of main in his district daily.

To exchange taps found defective.

To see that stand-posts and platforms are kept clean.

To open the scour valves periodically.

To report breakages, or ill usage of taps and waste of water.

To oil the valve spindles and to see that the valves are in working order.

He should report to the office at least once daily.

He should know the position of every valve in his district and to what extent the closing or opening of the valves affects the general distribution; also how in case of fire to arrange the valves so that the whole supply of water can be directed to a certain locality.

69. By judiciously transferring these Inspectors from one district to another, they gradually learn the positions of the taps, valves, mains, &c., in the whole station.

70. Each stand-post and tap should be numbered and a map carefully kept up to date should be maintained, showing the positions and numbers of stand-posts, taps and valves. Copies, preferably ferrotypes, of this map should be provided for the Cantonment Magistrate, Deputy Commissioner, and Staff Officers or others, who may have to refer in correspondence to the water-supply.

71. Stand-posts require repainting every third year. To avoid obliteration of the numbers and the expense of re-numbering, it is advisable to have the numbers cast on stand-post covers by the makers.

72. When carrying out the distribution scheme of a water-works, careful record on plans or maps should be kept of the position of every pipe, valve, &c., showing size of pipes, depths below ground level, and the accurate position of sluice valves, air valves, hydrants, &c., with reference to some permanent building. Neglect of this precaution causes endless trouble sometimes, as after a lapse of years, with frequent changes of officers and

subordinates, valves and sometimes long lengths of pipe are apt to be "lost."

73. In water heavily charged with lime, the gun-metal faces and spindles of sluice valves speedily become coated, and the valve becomes unworkable and has to be removed to be cleaned. To avoid this, valves should be regularly worked once a month. Meters, *too*, frequently are rendered unworkable from this cause and require periodical cleaning. It is advisable to have one or two spare meters in store, and where a number are in use, a set of tools for repairing, and duplicate fittings should be kept in stock. In the working of and repairs to valves, taps, &c., the use of Neat's-foot oil and tallow should be avoided as far as possible, especially in localities inhabited by Hindus. The use of leather washers sometimes causes trouble unless the natives are assured that the leather is "goat" skin.

74. Air valves should be regularly tested to ascertain if they are in working order.

75. Regulating ferrules are preferable to meters where the supply is small and constant.

76. The 'head' of water at any given point is easily found by fixing by a union or coupling an ordinary steam-gauge on the tap; the pressure shown $\times$ 2·307 = head in feet.

77. Registers, posted daily, should be carefully maintained to show:—

Quantity of water in reservoirs, received from head-works, pumped, used, and so on.

Diagrams showing the consumption, &c., posted monthly or weekly, are very useful for easy reference.

78. Where pumping machinery is used, registers should be kept to show the boiler and engine in use, the quantity of fuel and material used, &c., thus—

Date.	Pump (or Engine) at work.	Boiler at work.	Commenced pumping, time.	Ceased work, time.	Quantity of water raised, gallons.	*Fuel used.*	
						Coal.	Firewood.

Materials used.						Remarks.
Cylinder oil.	Castor oil.	Tallow.	Cotton waste.			

subordinates, ... sometimes long lengths of pipe are apt to be "lost."

73. In ... the gun-metal faces and spindles of ... valve becomes unworkab' ... alves should b rendered is advis are in kept i of N ciall son is

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						Coal.	Firewood.

Materials used.						Remarks.
Cylinder oil.	Castor oil.	Tallow.	Cotton waste.			

From the monthly totals the cost of pumping can be readily ascertained.

79. Under the orders of Government of India the charges for maintenance are debited as follows :—

(1). *Maintenance charges.*—To include all establishment, labor and materials necessary to maintain and keep in repair the buildings, pipes, stand-posts, reservoirs, &c., debitable to Military Works Funds.

(2). *Pumping charges.*—(*a*) all establishment and labor necessary for pumping the water, debitable to Military Estimates; (*b*) cost of fuel and other material required for pumping debitable to Commissariat Estimates.

(3). *Working charges.*—All establishment and labor necessary to work the water-supply scheme, debitable to Military Estimates.

80. **Books of reference.**—The following books are recommended on this subject, and they should be consulted when a large project is under preparation :—

No.	Name.	Price.
1	Practical Hydraulics, [illegible], by Thomas Box, ...	[illegible]
2	Treatise on Hydraulic and Water-supply Engineering, 1896, by J. T. Fanning, C.E., ...	[illegible]
3	Water-supply of Towns, [illegible], by [illegible], ...	[illegible]
4	Water-supply of Barracks and Cantonments, [illegible], by Major Scott-Moncrieff, ...	[illegible]
5	Water Pipe Discharge Diagrams, [illegible], by [illegible], C.E., ...	...
6	Manual of Hydraulics, 18[illegible], 2nd Edition, by [illegible] Love, ...	[illegible]

Rules for collecting Water for Sanitary Examination.

1. Only clean glass bottles fitted with glass stoppers should be employed for the collection of water samples. For bacterial examination they should be boiled or steamed for one hour on three successive days, and then carefully closed, a cap of clean paper or cloth being tied over the stopper.

2. On no account should earthenware jars or other vessels closed with corks be used.

3. Before a sample is taken, it is advisable to wash out the bottle in which it is to be collected repeatedly with some of the water to be examined.

4. If the water is to be taken from a stream or lake, the sample should be collected as far away from the bank as possible, and the closed bottle gently plunged in so as to bring the mouth some 3 or 4 inches below the water surface; in that position the stopper should be withdrawn and the bottle filled.

5. In taking a sample from a tap or pipe supply, the water should be allowed to run away for a couple of minutes or more before the bottle is filled.

6. When the sample is to be taken from a well, all stagnant water should first be withdrawn, and efforts should be made to lower the collecting bottle direct into the water: this will necessitate the attachment of a weight or stone to the bottle in order to make it sink below the surface. Care should be taken to see that any such weight or stone is clean. If this cannot be done, the water must be drawn up by a bucket or whatever arrangement is available and the collecting bottle filled from it: a tube well drawing from the subsoil water, free from risk of contamination, is recommended.

7. For a complete sanitary examination, at least two pints of the water sample are necessary.

8. Having collected the water sample, it should be despatched with the least possible delay for examination, as changes in some of the most important constituents take place with great rapidity, more especially in hot weather.

9. Pending examination, water samples should be kept in a dark and cool place.

10. The fullest information ought always to be furnished with the sample, the following being the most important particulars :—

(*a*). Source: whether from tank or cistern, main or house pipe, spring, river, stream, lake or well.

(*b*). If a well; depth, diameter, strata through which sunk; whether imperviously steined and how far down it is so protected. Particulars as to whether the well is open or covered, and what arrangements exist for withdrawing the water.

(*c*). Possibilities of impurities reaching the water, notably distance of well from middens, manure heaps, cesspools, stables, &c., &c., proximity of cultivated land.

(*d*). If a surface water, or rain water, nature of the collecting surface and conditions of storage.

(*e*). Meteorological conditions, with reference to recent drought or excessive rainfall.

(*f*). A statement of the existence of any disease supposed to be connected with the water-supply, or any other special reasons for requiring analysis.

11. Any further information that can be obtained will always be useful.

12. Each bottle should be distinctly labelled, so as to correspond with the official letter or invoice.

13. For bacterial examination the sample should always be taken by the officer making the examination, as many technical details have to be observed in its collection.

CALCULATIONS.

1. Calculations, showing the weight borne on foundations, the scantling of the *principal* rafter, and of the common rafters, purlins, and battens in all timber roofs, also of the strap and bolt at the foot of the principal rafter, and of the tie-beam, *where the latter has to carry a ceiling;* the dimensions of *all* the parts of an iron or steel roof-truss; the scantlings of all floor joists, whether of wood or iron, and of all iron or steel girders should, when necessary, accompany every rough Project. The above is a general enumeration of the calculations necessary in the preparation of projects, but other cases may occur in which it may be necessary for the Executive Engineer to submit calculations; *e.g.*, for the [illegible] retaining walls, of bridges in Cantonment, roads, &c., &c.

2. Calculations should be as concise as possible, [illegible] giving all that is really necessary: *e.g.*, in the calculations [illegible] bers in a roof truss, it will only be necessary to [illegible] of the principal rafter, as all the other portions [illegible] by calculation a smaller scantling than can be [illegible] scantling of the principal rafter being [illegible] straining-beam (where such exists) may [illegible] scantling; and in most cases all the [illegible] with the side of the square equal [illegible] principal rafter; but, where the [illegible] calculation for it will be necessary. [illegible] calculations of all the parts [illegible] generally be constructed *pract*[illegible]

3. Examples are given [illegible] required. A reference [illegible] structions given above [illegible] should be submitted [illegible] positions which [illegible]

4. *All uniformly-loaded beams, timbers, &c.*, are to be calculated by *both* the Formulæ for Transverse Strain, *and* by that for Deflection, the larger result in each case being invariably adopted.

5. In calculating the scantlings of *battens*, *common rafters*, and *purlins*, the vertical weight of the roof covering is to be reduced to normal pressure, by multiplying the actual weight by the cosine of the angle of pitch of the roof; to this should be added the pressure of wind, the weight of the piece itself, and that of the pieces over it, the sum of the whole being expressed as W in the formulæ. The calculation should then be made by the formulæ for *Transverse Strain* and *Deflection*.

6. A reference to the examples will show precisely the method which should be adopted in each of the above cases.

7. A sketch of the truss, drawn in simple lines to a convenient scale, should accompany the calculation of strains on a roof, the span of the truss being taken from the centre of the walls on each side. The common rafters may be taken as of the same length as the principal rafters. The adoption of this method will insure the same dimensions being measured off by every one, both in making, and in examining, calculations.

8. In working with logarithms, quantities should be taken out to the number of places of decimals which corresponds to the number of figures to which the logarithm tables are worked out. For instance, taking Chambers's Logarithm Tables, which are worked out to five figures, numbers above ten thousand need not generally be worked out to decimals at all, thousands should usually be worked out to one, and hundreds to two, places of decimals. Generally it will be unnecessary to work out numbers to more than two places of decimals.

9. Tables of principal rafters, and of the straps and bolts at their feet, calculated for King-post trusses constructed with sál wood timber, are also given. These may also be used for teak in cases where an approximate result is sufficient. These Tables assume that the walls on which the trusses rest are 18 inches thick, and the span of the truss is therefore, in each case, 18 inches more than the clear internal span. The Tables give dimensions for spans from 10 to 26 feet, the differences in each case being 2 feet, and for intervals from 4 to 8 feet, the differences being 3 inches. In the Table for straps and bolts, the dimensions of each part of the strap are given above, and the diameter of the bolt below, in each case.

10. These Tables are not intended to supersede original calculations

in connoction with projects of large importance: to these their relation will be that of a check. But in minor projects, the Tables may be utilized as a substitute for original calculations: and in such instances, a special and clear reference should be made to the particular table made use of.

11. The above instructions have been given for roofs constructed in the ordinary way with *trusses*, *purlins*, *common rafters* and *battens*: but in the case where the roof covering is borne direct on *numerous purlins*, common rafters being omitted, the principal rafters must, in addition to the method indicated above, be calculated as *uniformly loaded*, and a given depth being assumed, the breadths of the sections obtained by each method must be added together to give the final section.

Notation.

The following Notation should be strictly followed in making calculations :—

i. *Forces*, ...	P = Any force or strain, in lbs. W = Uniformly distributed load on any given length or surface, in lbs. w = Any specified weight other than W, in lbs.
ii. *Strength of Materials (Constants).*	c = Safe crushing strain per square inch of section, in lbs. s = Safe shearing strain per square inch of section, in lbs.

ERRATUM.

Page 93, line 4 from bottom, *for* "diameter," *read* "dimension."

v. *Dimensions*, ...	Formulæ V., VI.) l = Unsupported length of beam, girder, &c., in inches.

v. *Dimensions,* (continued),	L = Unsupported length of beam, girder, &c., in feet.
	S = Any sectional area in square inches.
	δ = Deflection of beam, girder, &c., in inches.
vi. *Calculations by Moments of Inertia,*	I = Moment of Inertia, (*see* Table VII.)
	μ = „ Resistance, (do.)
	v = Distance of neutral axis from tension flange, (*see* Table VII.), in inches.

Formulæ.

In the following formulæ it has been assumed, that—

(i). In beams under a permanent dead load—

$\delta = \frac{L}{40}$ is the maximum safe deflection, and that in transverse strain a factor of safety of 10 should be allowed.

(ii). In beams under a partly permanent and partly occasional load—

$\delta = \frac{L}{20}$ is the maximum safe deflection, and that in transverse strain a factor of safety of 6 should be allowed.

General Formulæ for rectangular wooden beams, planks, &c., uniformly loaded, supported at both ends.

I. For Deflection—

With permanent load, $d = \sqrt[3]{\dfrac{25\ L^2 \times W}{b \times p}}$

With part permanent and part occasional load, $d = \sqrt[3]{\dfrac{25\ L^2 \times W}{2 \times b \times p}}$

II. For Transverse Strain—

With permanent load, $d = \sqrt[2]{\dfrac{10 \times L \times W}{2 \times r \times b}}$

With part permanent and part occasional load, $d = \sqrt[2]{\dfrac{6 \times L \times W}{2 \times r \times b}}$

III. By substituting the values of p and r given in Table V. in the above formulæ, the following simple formulæ, which are recommended for general use in practice, are derived.

VI. Formulæ for iron struts, where h = least sectional dimension in inches of triangle, square, or polygon circumscribing the section.

(i). When the strut is *fixed* or *rivetted* at both ends—

$$P = \frac{S \times c}{1 + a\frac{l^2}{h^2}}.$$

(ii). When the strut is *rounded* or *pin-jointed* at both ends—

$$P = \frac{S \times c}{1 + 4a\frac{l^2}{h^2}}.$$

VII. Formulæ for iron girders—

W = safe load in pounds uniformly distributed.

$$W = \frac{8 \times t \times I}{l \times v} \text{ or } = \frac{8 \times c \times I}{l \times (d - v)}$$

the expression giving the smaller value to W to be used, (*see* Table VII.)

Formulæ for calculating the various strains in King-post and Queen-post trusses.

Here W = Weight of roof covering, (Table III.),
" common rafters,
" purlin (or purlins),
" principal rafter,
" ironwork, (Table I.),
} borne vertically by *one* principal rafter, in lbs.

Normal pressure of wind, (page 98),

w = $\frac{5}{8}$ (tie-beam + ceiling on it)
two struts,
one King-post, or (two Queen-posts
+ straining beam
+ straining sill).
} in lbs.

θ = inclination of roof to the horizon.

VIII. For a King-post truss—

(*a*). Thrust on heel of principal rafter, $= \left(\frac{13}{16} W + \frac{w}{2}\right) \operatorname{cosec} \theta.$*

(*b*). Tension on tie-beam, ... $= \left(\frac{13}{16} W + \frac{w}{2}\right) \cot \theta.$

(*c*). Thrust on strut, ... $= \frac{5}{16} W \operatorname{cosec} \theta.$

(*d*). Tension on King-post,... ... $= \frac{5}{8} W + w.$

* $\frac{13}{16} \operatorname{cosec} 26^\circ 35' = 1{\cdot}815.$

IX. For a Queen-post truss—

(*a*). Thrust on heel of principal rafter, $= \left(\frac{5}{6} W + \frac{w}{2}\right) \operatorname{cosec} \theta.$

(*b*). Tension on tie-beam, ... $= \left(\frac{5}{6} W + \frac{w}{2}\right) \cot \theta.$

(*c*). Thrust on strut, ... $= \frac{W}{6} \operatorname{cosec} \theta.$

(*d*). Tension on Queen-post, ... $= \frac{W}{3} + \frac{w}{2}.$

(*e*). Thrust on straining-beam, ... $= \left(\frac{2}{3} W + \frac{w}{2}\right) \cot \theta.$

(*f*). Thrust on straining-sill, ... $= \frac{W}{6} \cot \theta.$

X. Formulæ for bolt and strap at foot of principal rafter in a timber truss—

P = tension on tie-beam = strain on heel strap.

XI. For section of each limb of heel strap—

$$S = \frac{P}{2t}.$$

N.B.—Round the bolt $\frac{5}{8}$ths of this effective section to be given on each side of the eye.

XII. For diameter of bolt, in inches.

$$\text{Diameter} = \frac{\text{Tension on tie-beam}}{b \times \frac{5}{3}c}.$$

In calculating the working resistance of a rivetted joint—

(i). Allow for a shearing strain of 4 tons per square inch.

(ii). Allow for a bearing strain of 5 tons per square inch.

Then if n = number of rivets.

d = diameter of rivets, in inches.

t = thickness of plate, ,, ,,

We have for (i) Resistance $= n \times \pi \times \frac{d^2}{4} \times 4$ tons,

and for (ii) ,, $= n \times d \times t \times 5$,,

No rivet hole should be nearer to the edge of the bar than its own diameter or nearer the next than $1\frac{1}{2}$ times its diameter.

XIII. Water-supply—

In working out distribution schemes very different results are obtained by employing the different formulæ given in the text-books on the subject. For ordinary circumstances it has been decided to adopt Fanning's formulæ with varying co-efficients which give medium results. Larger pipes, 3-inch and upwards, will be considered "slightly tuberculated," smaller pipes "foul."

Adopting the foregoing notation, this formula may be written as under—

$$G = \sqrt{\frac{5{\cdot}5767 \times d^5 \times H}{m \times L}},$$

where

G = discharge in gallons per minute.

d = diameter of pipe, in inches.

H = head, in feet.

L = length of pipe, in feet.

m = a varying co-efficient the value of which varies only with diameter of the pipe, and is given in Tables, pages 124-131.

NOTE.—Log $5{\cdot}5767 = {\cdot}7463803$.

For velocity in feet per second—

$$V = \frac{G}{2d^2} \text{ approximately.}$$

For further details regarding formulæ for Water-supply in pipes, *see* Pamphlet issued by Director-General, Military Works, in January, 1898.

Wind Pressure.

The Meteorological Reporter to the Government of India considers a cyclone may exert a pressure of 60 lbs. per square foot on a surface perpendicularly opposed to it. Professor Unwin in his paper published in the R. E. Professional Papers for 1897 has shown that the real pressure of wind on roofs is very different to that hitherto supposed to be the case. The Board of Trade have, however, not altered their rules, and as work-people, snow, &c., have to be allowed for as temporary load in any case, it has been decided to continue to consider this to be wind pressure which for the purpose of calculations may be taken as 60 lbs. per square foot maximum.

If P = intensity of wind's pressure in lbs. per square foot.

θ = inclination of roof to horizontal.

P_n = intensity of wind's pressure normal to roof surface.

Then

$$P_n = P \sin \theta^{\,1{\cdot}84 \cos \theta - 1}$$

If P = 60 lbs. per square foot.

Then for roofs sloping $\frac{1}{1}$, $P_n = 54$ lbs.

" " " $\frac{2}{3}$, $P_n = 42$ "

" " " $\frac{1}{2}$, $P_n = 35$ "

" " " $\frac{1}{3}$, $P_n = 25$ "

But as this gives an unnecessarily high factor of safety in the case of light roofs, the wind pressure normal to a roof's surface need not be considered greater than the weight of the roof covering, subject to a minimum of half the values given above for P_n. It should be noted that it is particularly necessary to tie down light roofs securely to the walls or pillars on which they rest.

Tables.

Table I.

Live loads on floors = in barracks and officers' messes 112 lbs. per square foot dead load.

In officers' quarters 90 lbs. per square foot dead load.

In godowns special calculations of weight must always be made.

Ironwork in calculating principal rafters = 20 lbs. per principal rafter.

In calculating weights of built iron girders, add 10 per cent. for extra weight at joints, rivet heads, &c.

Table II.

Safe Loads on Foundations.

In loamy soil, such as that of the Upper Provinces, ...	·80	ton per sq. ft.
In stiff clays, ...	1 to 1·5	,, ,,
In rock, ...	1·5 to 3·5	,, ,,

Table III.

Weights of Materials.

Brickwork, bricks, ...	120	lbs. per c. ft.
Masonry, stone, ...	156	,, ,, ,,
Concrete, ...	115	,, ,, ,,
Plaster, ...	106	,, ,, ,,
Teak wood, ...	52	,, ,, ,,
Sál, ...	62	,, ,, ,,
Deodar, ...	40	,, ,, ,,
Chír, ...	32	,, ,, ,,
Sun dried brickwork in mud, ...	100	,, ,, ,,
Clay, ...	130	,, ,, ,,
Loam, ...	110	,, ,, ,,
Sand, ...	125	,, ,, ,,

Corrugated iron roofing, 22 B. W. G., ...	2 lbs. per sq. ft.
Naini Tal pattern roofing, 22 B. W. G., including 1 inch planking, ...	5 " " "
Mangalore tiling, ...	10 " " "
Nurrea tiling, single, with framing, ...	12 " " "
" " double " " ...	23 " " "
Goodwyn tiling, single, ...	17 " " "
" " double, ...	31 " " "
Pan tiles, ...	10 " " "
Mud plaster and reed ceiling, ...	6 " " "
Wrought-iron, ...	·28 " " c. in.
Cast-iron, ...	·27 " " "
Steel, ...	·288 " " "
Brass, ...	·3 " " "
Copper, ...	·32 " " "
¼″-thick iron plate, ...	10 " " s. ft.
Including battens { Double Allahabad tiling,* ...	34 " " "
Including battens { Single " " † ...	17 " " "
Including battens { Country tiling, ...	14 " " "
9″ Thatching, including bamboo frames, ...	10 " " "

Weights reduced to normal slope of roof 26° 35′.

Double Allahabad tiling, ...	30 lbs. per sq. ft.
Single " " ...	15 " " "

Allahabad Tiles.

	lbs.	oz.
* *Double Tiling*—		
1 Flat tile, dry, ...	8	12
1 Semi-hexagonal tile, dry, ...	5	12
1 Flat tile, wet, ...	9	14
1 Semi-circular tile, wet, ...	4	14
Battens (say), ...	4	4
	33	8

	lbs.	oz.
† *Single Tiling*—		
1 Flat tile, wet, ...	9	14
1 Semi-circular tile, wet, ...	4	14
Battens (say), ...	2	0
	16	12

Table IV.

Safe Strain on a Square Inch, in lbs.

Materials.	Tensile Strain. t	Crushing Strain. c	Shearing Strain. s
Brickwork, ...	...	5 tons per sq. foot.	...
Concrete, ...	...	5 tons per sq. foot.	...
Teak wood, ...	1,353	1,210	..
Sál "	1,210	1,210	...
Deodar, ...	700	700	..
Chír, ...	700	700	...
Deal, ...	1,200	600	...
Pine, red,...	1,400	800	...
Wrought-iron, ...	11,200	8,960	11,200
" " rivetted work, ...	8,960	8,960	8,960
" " bolts, tie-rods, &c.,	11,200	8,960	6,720
Screws, nuts, &c., ...	...	...	4,480
Cast-iron, ...	3,750	26,800	6,720
Steel, ...	14,000	11,200	11,200
Copper bolts, ...	8,690	...	...
Gwalior sandstone, ...	225	225	...

Table V.

Constants for Timber, &c.

Name of Timber, &c.		Deflection.	Transverse Strain.
Botanical.	Common.	p*	r†
Tectona grandis, ...	Teak, ...	2,200	470
Shorea robusta, ...	Sál, ...	2,500	550
Cedrus deodara, ...	Deodar, ...	1,800	300
Pinus longifolia, ...	Chír, ...	1,800	300
	Gwalior sandstone, ...	...	60
	Pine, red, ...	4,600	510

Table VI.

Constants of Iron Struts.

For wrought-iron, $a = \frac{1}{3000}$

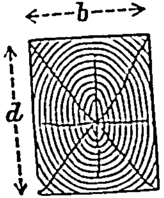
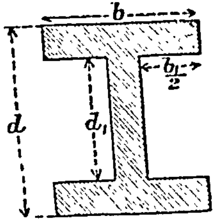
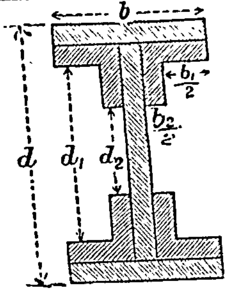
" cast- " $a = \frac{1}{400}$

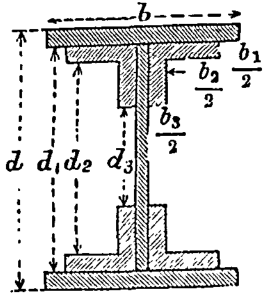
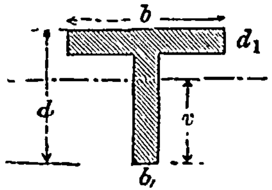
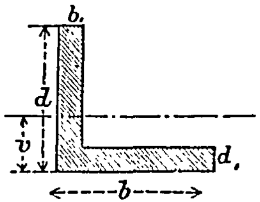
* The Modulus of Elasticity of these timbers is equal to 432 times p, or $p = \frac{E}{432}$.

† r is the load required to break a bar of 1 inch square supported at two points 1 foot apart, and loaded in the middle between the points of support, and is equal to $\frac{1}{18}$ of the Modulus of Rupture, or $r = \frac{f_o}{18}$.

Table VII.

Moments of Inertia, &c.

Cross Section.		Moment of Inertia, I.	Moment of Resistance, $\mu = \frac{t \times I}{v}$ or $= \frac{c \times I}{d - v}$	Distance of neutral axis from tension edge. v
	I.	$\frac{bd^3}{12}$	$\frac{tbd^2}{6}$	$\frac{d}{2}$
	II.	$\frac{bd^3 - b_1 d_1^3}{12}$	$\frac{2 \times c \times I}{d}$	$\frac{d}{2}$
	III.	$\frac{bd^3 - (b_1 d_1^3 + b_2 d_2^3)}{12}$	$\frac{2 \times c \times I}{d}$	$\frac{d}{2}$

 	IV.	$\frac{bd^3 - (b_1 d_1^3 + b_2 d_2^3 + b_3 d_3^3)}{12}$	$\frac{2 \times c \times I}{d}$	$\frac{d}{2}$
 	V.	$\frac{1}{3}\{b_1 v^3 - (b - b_1)(d - d_1 - v)^3 + b(d-v)^3\}$	$\frac{t \times I}{v}$	$d - \frac{1}{2}\left(\frac{bd_1^2 - b_1 d_1^2 + b_1 d^2}{bd_1 - b_1 d_1 + b_1 d}\right)$
 	VI.	$\frac{1}{3}\{bv^3 - (b-b_1)(v-d_1)^3 + b_1(d-v)^3\}$	$\frac{\frac{3}{4} {}^* c \times I}{d - v}$	$\frac{1}{2}\left(\frac{bd_1^2 - b_1 d_1^2 + b_1 d^2}{bd_1 - b_1 d_1 + b_1 d}\right)$

* A number of experiments conducted by Mr. Molesworth, C.E., showed that ┬-iron is stronger than ┐-iron of the same section, as the latter buckles sooner; for angle-iron the ordinary constants must, it was found, be multiplied by ¾ to give a section of equal strength.

Value of bd^3 for { Value of
”

DEPTH.	BREADTH. 1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$		2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$		3	$3\frac{1}{4}$	$3\frac{1}{2}$
1	1·0	1·2	1·5	1·7		2·0	2·2	2·9	2·7		3·0	3·2	3·5
$1\frac{1}{4}$	2·0	2·4	2·9	3·4		3·9	4·4	4·9	5·4		5·9	6·3	6·8
$1\frac{1}{2}$	3·4	4·2	5·1	5·9		6·7	7·6	8·4	9·3		10·1	11·0	11·8
$1\frac{3}{4}$	5·4	6·7	8·0	9·4		10·7	12·1	13·4	14·7		16·1	17·4	18·8
2	8·0	10·0	12·0	14·0		16·0	18·0	20·0	22·0		24·0	26·0	28·0
$2\frac{1}{4}$	11·4	14·2	17·1	19·9		22·8	25·6	28·5	31·3		34·2	37·0	39·9
$2\frac{1}{2}$	15·6	19·5	23·4	27·3		31·2	35·2	39·1	43·0		46·9	50·8	54·7
$2\frac{3}{4}$	20·8	26·0	31·2	36·4		41·6	46·8	52·0	57·2		62·4	67·6	72·8
3	27·0	33·7	40·5	47·2		54·0	60·7	67·5	74·2		81·0	87·7	94·5
$3\frac{1}{4}$	34·3	42·9	51·5	60·1		68·7	77·2	85·8	94·4		103	112	120
$3\frac{1}{2}$	42·9	53·6	64·3	75·0		85·8	96·5	107	118		129	139	150
$3\frac{3}{4}$	52·7	65·9	79·1	92·3		105	119	132	145		158	171	185
4	64·0	80·0	96·0	112		128	144	160	176		192	208	224
$4\frac{1}{4}$	76·8	96·0	115	134		154	173	192	211		230	249	269
$4\frac{1}{2}$	91·1	114	137	159		182	205	228	251		273	296	319
$4\frac{3}{4}$	107	134	161	188		214	241	268	295		322	348	375
5	125	156	187	219		250	281	312	344		375	406	437
$5\frac{1}{4}$	145	181	217	253		289	326	362	398		434	470	506
$5\frac{1}{2}$	166	208	250	291		333	374	416	458		499	541	582
$5\frac{3}{4}$	190	238	285	333		380	428	475	523		570	618	665
6	216	270	324	378		432	486	540	594		648	702	756
$6\frac{1}{4}$	244	305	366	427		488	549	610	671		732	793	855
$6\frac{1}{2}$	275	343	412	481		549	618	687	755		824	893	961
$6\frac{3}{4}$	308	384	461	538		615	692	769	846		923	1000	1076
7	343	429	514	600		686	772	857	943		1029	1115	1200
$7\frac{1}{4}$	381	476	572	667		762	857	953	1048		1143	1238	1334
$7\frac{1}{2}$	422	527	633	738		844	949	1055	1160		1266	1371	1477
$7\frac{3}{4}$	465	582	698	815		931	1047	1164	1280		1396	1513	1629
8	512	640	768	896		1024	1152	1280	1408		1536	1664	1792
$8\frac{1}{4}$	562	702	842	983		1123	1263	1404	1544		1685	1825	1965
$8\frac{1}{2}$	614	768	921	1075		1228	1382	1535	1689		1842	1996	2149
$8\frac{3}{4}$	670	837	1005	1172		1340	1507	1675	1842		2010	2177	2345
9	729	911	1093	1276		1458	1640	1822	2005		2187	2369	2551
$9\frac{1}{4}$	791	989	1187	1385		1583	1781	1979	2176		2374	2572	2770
$9\frac{1}{2}$	857	1072	1286	1500		1715	1929	2143	2358		2572	2786	3001
$9\frac{3}{4}$	927	1159	1390	1622		1854	2085	2317	2549		2781	3012	3244
10	1000	1250	1500	1750		2000	2250	2500	2750		3000	3250	3500
	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$		2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$		3	$3\frac{1}{4}$	$3\frac{1}{2}$

b varying from 1 to 6.

d „ „ 1 to 10.

Breadth.										Depth.
3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6	
3·7	4·0	4·2	4·5	4·7	5·0	5·2	5·5	5·7	6·0	1
7·3	7·8	8·3	8·8	9·3	9·8	10·3	10·7	11·2	11·7	1¼
12·7	13·5	14·3	15·2	16·0	16·9	17·7	18·6	19·4	20·2	1½
20·1	21·4	22·8	24·1	25·5	26·8	28·1	29·5	30·8	32·2	1¾
30·0	32·0	34·0	36·0	38·0	40·0	42·0	44·0	46·0	48·0	2
42·7	45·6	49·4	51·3	54·1	57·0	59·8	62·6	65·5	68·3	2¼
58·6	62·5	66·4	70·3	74·2	78·1	82·0	85·9	89·8	93·7	2½
78·0	83·2	88·4	93·6	98·8	104	109	114	120	125	2¾
101	108	115	121	128	135	142	148	155	162	3
129	137	146	154	163	172	180	189	197	206	3¼
161	171	182	193	204	214	225	236	247	257	3½
198	211	224	237	250	264	277	290	303	316	3¾
240	256	272	288	304	320	336	352	368	384	4
288	307	326	345	365	384	403	422	441	461	4¼
342	364	387	410	433	456	478	501	524	547	4½
402	429	455	482	509	536	563	589	616	643	4¾
469	500	531	562	594	625	656	687	719	750	5
543	579	615	651	687	724	760	796	832	868	5¼
624	665	707	749	790	832	873	915	957	998	5½
713	760	808	855	903	951	998	1046	1093	1141	5¾
810	864	918	972	1026	1080	1134	1188	1242	1296	6
916	977	1038	1099	1160	1221	1282	1343	1404	1465	6¼
1030	1098	1167	1236	1304	1373	1442	1510	1579	1648	6½
1153	1230	1307	1384	1461	1538	1615	1692	1768	1845	6¾
1286	1372	1458	1543	1629	1715	1801	1886	1972	2058	7
1429	1524	1620	1715	1810	1905	2001	2096	2191	2286	7¼
1582	1687	1793	1898	2004	2109	2215	2320	2426	2531	7½
1746	1862	1978	2095	2211	2327	2444	2560	2677	2793	7¾
1920	2048	2176	2304	2432	2560	2688	2816	2944	3072	8
2106	2246	2386	2527	2667	2808	2948	3088	3229	3369	8¼
2303	2456	2610	2763	2917	3071	3224	3378	3531	3685	8½
2512	2680	2847	3015	3182	3350	3517	3685	3852	4020	8¾
2734	2916	3098	3280	3463	3645	3827	4009	4192	4374	9
2968	3166	3364	3562	3759	3957	4155	4353	4551	4749	9¼
3215	3429	3644	3858	4073	4289	4501	4716	4930	5144	9½
3476	3707	3939	4171	4403	4634	4866	5098	5329	5561	9¾
3750	4000	4250	4500	4750	5000	5250	5500	5750	6000	10
3¾	4	4¼	4½	4¾	5	5¼	5½	5¾	6	

Value of bd^2 for { Value of
"

Depth.	Breadth.											
	1	1¼	1½	1¾		2	2¼	2½	2¾		3	3¼	3½
1	1·0	1·2	1·5	1·7		2·0	2·2	2·5	2·7		3·0	3·2	3·5
1¼	1·6	2·0	2·3	2·7		3·1	3·5	3·9	4·3		4·7	5·1	5·5
1½	2·2	2·8	3·4	3·9		4·5	5·1	5·6	6·2		6·7	7·3	7·9
1¾	3·1	3·8	4·6	5·4		6·1	6·9	7·7	8·4		9·2	10·0	10·7
2	4·0	5·0	6·0	7·0		8·0	9·0	10·0	11·0		12·0	13·0	14·0
2¼	5·1	6·3	7·6	8·9		10·1	11·4	12·7	13·9		15·2	16·2	17·7
2½	6·2	7·8	9·4	10·9		12·5	14·1	15·6	17·2		18·7	20·3	21·9
2¾	7·6	9·5	11·3	13·2		15·1	17·0	18·9	20·8		22·7	24·6	26·5
3	9·0	11·2	13·5	15·7		18·0	20·2	22·5	24·7		27·0	29·2	31·5
3¼	10·6	13·2	15·8	18·5		21·1	23·8	26·4	29·0		31·7	34·3	37·0
3½	12·2	15·3	18·4	21·4		24·5	27·6	30·6	33·7		36·7	39·8	42·9
3¾	14·1	17·6	21·1	24·6		28·1	31·6	35·2	38·7		42·2	45·7	49·2
4	16·0	20·0	24·0	28·0		32·0	36·0	40·0	44·0		48·0	52·0	56·0
4¼	18·1	22·6	27·1	31·6		36·1	40·6	45·2	49·7		54·2	58·7	63·2
4½	20·2	25·3	30·4	35·4		40·5	45·6	50·6	55·7		60·7	65·8	70·9
4¾	22·6	28·2	33·8	39·5		45·1	50·8	56·4	62·0		67·7	73·3	79·0
5	25·0	31·2	37·5	43·7		50·0	56·2	62·5	68·7		75·0	81·2	87·5
5¼	27·6	34·5	41·3	48·2		55·1	62·0	68·9	75·8		82·7	89·6	96·5
5½	30·2	37·8	45·4	52·9		60·5	68·1	75·6	83·2		90·7	98·3	106
5¾	33·1	41·3	49·6	57·9		66·1	74·4	82·7	90·9		99·2	107	116
6	36·0	45·0	54·0	63·0		72·0	81·0	90·0	99·0		108	117	126
6¼	39·1	48·8	58·6	68·4		78·1	87·9	97·7	107		117	127	137
6½	42·2	52·8	63·4	73·9		84·5	95·1	106	116		127	137	148
6¾	45·6	57·0	68·3	79·7		91·1	103	114	125		137	148	159
7	49·0	61·2	73·5	85·7		98·0	110	122	135		147	159	171
7¼	52·6	65·7	78·9	92·0		105	118	131	145		158	171	184
7½	56·2	70·3	84·4	98·4		112	127	141	155		169	183	197
7¾	60·1	75·1	90·1	105		120	135	150	165		180	195	210
8	64·0	80·0	96·0	112		128	144	160	176		192	208	224
8¼	68·1	85·1	102	119		136	153	170	187		204	221	238
8½	72·2	90·3	108	126		144	163	181	199		217	235	253
8¾	76·6	95·7	115	134		153	172	191	211		230	249	268
9	81·0	101	121	142		162	182	202	223		243	263	283
9¼	85·6	107	128	150		171	193	214	235		257	278	299
9½	90·2	113	135	158		180	203	226	248		271	293	316
9¾	95·1	119	143	166		190	214	238	261		285	309	333
10	100	125	150	175		200	225	250	275		300	325	350
	1	1¼	1½	1¾		2	2¼	2½	2¾		3	3¼	3½

SCANTLINGS OF PRINCIPAL RAFTERS.

Double Allahabad Tiling.

King-Post Trusses of Sál and Teak.

Clear internal Spans.

Distance apart of trusses.	10′	12′	14′	16′	18′	20′	22′	24′	26′
4′ 0″	2″ × 3″	2½″ × 3″	2¼″ × 3¼″	2½″ × 3¼″	2½″ × 3½″	2¾″ × 3¾″	2¾″ × 4″	3″ × 4″	3″ × 4¼″
4′ 3″	2¼″ × 3″	do.	2½″ × 3¼″	2½″ × 3½″	2¾″ × 3½″	2¾″ × 4″	3″ × 4″	3″ × 4¼″	do.
4′ 6″	do.	2¼″ × 3¼″	do.	2¾″ × 3½″	2¾″ × 3¾″	3″ × 3¾″	3″ × 4¼″	do.	3¼″ × 4¼″
4′ 9″	2¼″ × 3¼″	2½″ × 3¼″	2½″ × 3½″	2¾″ × 3¾″	2¾″ × 4″	3″ × 4″	do.	3¼″ × 4¼″	3¼″ × 4½″
5′ 0″	do.	do.	2½″ × 3¾″	do.	3″ × 3¾″	3″ × 4¼″	3¼″ × 4¼″	3¼″ × 4½″	3¼″ × 4¾″
5′ 3″	do.	2½″ × 3½″	do.	2¾″ × 4″	3″ × 4″	3¼″ × 4¼″	3¼″ × 4½″	3¼″ × 4¾″	3½″ × 4¾″
5′ 6″	2½″ × 3″	do.	2¾″ × 3¾″	3″ × 4″	3″ × 4¼″	do.	3¼″ × 4¾″	3½″ × 4¾″	3½″ × 5″
5′ 9″	2½″ × 3¼″	do.	do.	do.	3¼″ × 4″	3¼″ × 4½″	3½″ × 4½″	3½″ × 5″	do.
6′ 0″	do.	2¾″ × 3½″	2¾″ × 4″	3″ × 4¼″	3¼″ × 4¼″	3¼″ × 4¾″	3½″ × 4¾″	do.	3¾″ × 5″
6′ 3″	2½″ × 3½″	2¾″ × 3¾″	3″ × 4″	do	3¼″ × 4½″	3½″ × 4¼″	3½″ × 5″	3¾″ × 5″	3¾″ × 5¼″
6′ 6″	do.	do.	do.	3¼″ × 4¼″	do.	3½″ × 4¾″	do.	3¾″ × 5¼″	4″ × 5¼″
6′ 9″	2¾″ × 3½″	3″ × 3¾″	do.	do.	3¼″ × 4¾″	3½″ × 5″	3¾″ × 5″	4″ × 5″	do.
7′ 0″	do.	do.	3″ × 4¼″	3¼″ × 4½″	3½″ × 4½″	do.	do.	4″ × 5¼″	4″ × 5½″
7′ 3″	do.	3″ × 4″	3¼″ × 4¼″	3¼″ × 4¾″	3½″ × 4¾″	3¾″ × 5″	3¾″ × 5¼″	4″ × 5½″	4″ × 5¾″
7′ 6″	2¾″ × 3¾″	do.	do.	do.	do.	do.	4″ × 5¼″	4″ × 5¾″	4¼″ × 5½″
7′ 9″	do.	3″ × 4¼″	3¼″ × 4½″	3½″ × 4½″	3½″ × 5″	3¾″ × 5¼″	do.	do.	4¼″ × 5¾″
8′ 0″	2¾″ × 4″	do.	do.	3½″ × 4¾″	3¾″ × 5″	4″ × 5″	4″ × 5½″	4¼″ × 5¾″	4¼″ × 6″

For deodar, multiply section in above Table by $\frac{1210}{700} = 1{\cdot}72$.

Example.—Span 20 feet, trusses 8 feet apart. *See* Table, for sál 4″ × 5″ = 20; for deodar 20 × 1·72 = 34·4. Make 5″ × 7″.

SCANTLINGS OF PRINCIPAL RAFTERS.

Mangalore Tiling.

King-Post Trusses of Teak.

Clear internal Spans.

Distance apart of trusses.	10′	12′	14′	16′	18′	20′	22′	24′	26′
4′ 0″	1½″ × 2½″	1¾″ × 2½″	1½″ × 2¾″	2″ × 3″	2½″ × 3″	2½″ × 3¾″	2½″ × 3¾″	2½″ × 3¾″	2½″ × 3¾″
4′ 3″	1½″ × 2¾″	1¾″ × 2¼″	2″ × 2¾″	do.	2½″ × 3¼″	2½″ × 3½″	do.	2½″ × 3¾″	2¾″ × 3½″
4′ 6″	1¾″ × 2½″	do.	do.	2¼″ × 3″	do.	do.	2½″ × 3½″	do.	2¾″ × 3¾″
4′ 9″	do.	2″ × 2¾″	2″ × 3″	2¼″ × 3¼″	2½″ × 3¼″	do.	2½″ × 3¾″	2½″ × 3½″	2¾″ × 4″
5′ 0″	do.	do.	2¼″ × 3″	do.	do.	2½″ × 3½″	2½″ × 3½″	2¾″ × 4″	3″ × 3¾″
5′ 3″	1¾″ × 2¾″	2″ × 3″	do.	do.	do.	2½″ × 3¾″	2½″ × 3¾″	do.	do.
5′ 6″	do.	do.	2¼″ × 3¼″	2½″ × 3¼″	2½″ × 3½″	2¾″ × 3½″	2¾″ × 4″	3″ × 3¾″	3″ × 4″
5′ 9″	2″ × 2¾″	2¼″ × 3″	do.	do.	2½″ × 3½″	do.	3″ × 3¾″	3″ × 4″	3″ × 4½″
6′ 0″	do.	do.	2¼″ × 3¼″	do.	2½″ × 3½″	2¾″ × 4″	do.	do.	3¼″ × 4½″
6′ 3″	2″ × 3″	2¼″ × 3¼″	do.	2½″ × 3½″	do.	do.	3″ × 4″	3″ × 4½″	do.
6′ 6″	do.	do.	do.	do.	2¾″ × 3¾″	3″ × 3¾″	do.	do.	3¼″ × 4½″
6′ 9″	2¼″ × 3″	do.	do.	2½″ × 3½″	2¾″ × 4″	3″ × 4″	3″ × 4½″	3¼″ × 4½″	3¼″ × 4¾″
7′ 0″	do.	2½″ × 3¼″	2½″ × 3½″	do.	3″ × 3¾″	do.	3¼″ × 4½″	3¼″ × 4½″	do.
7′ 3″	do.	do.	2½″ × 3¾″	2¾″ × 4″	do.	3″ × 4¼″	do.	do.	3½″ × 4¾″
7′ 6″	do.	do.	do.	do.	3″ × 4″	do.	3½″ × 4½″	3½″ × 4¾″	do.
7′ 9″	2¼″ × 3¼″	do.	2¾″ × 3½″	3″ × 3¾″	do.	3¼″ × 4½″	do.	do.	3½″ × 5″
8′ 0″	do.	2½″ × 3½″	do.	do.	3″ × 4½″	do.	3½″ × 4¾″	3½″ × 4¾″	3½″ × 5¼″

For dimensions of strap and bolt at foot of Principal Rafter and at the head and foot of King-post *see* pages 113 and 114.

STRAP AND BOLT AT FOOT OF PRINCIPAL RAFTER.

DOUBLE ALLAHABAD TILING.

King-Post Trusses of all kinds of Timber.

Clear internal Spans.

Distance apart of trusses.	10′	12′	14′	16′	18′	20′	22′	24′	26′
4′ 0″	$1\frac{1}{4}'' \times \frac{1}{4}''$ $\frac{3}{4}''$	$1\frac{1}{4}'' \times \frac{1}{4}''$ $\frac{3}{4}''$	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1''$	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1''$	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1''$	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1''$	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$
4′ 3″	do.	do.	do.	do.	do.	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$	do.	do.	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$
4′ 6″	do.	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1''$	do.	do.	do.	do.	do.	$1\frac{1}{2}'' \times \frac{1}{4}''$ $1\frac{1}{4}''$	do.
4′ 9″	do.	do.	do.	do.	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$	do.	do.	do.	do.
5′ 0″	do.	do.	do.	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$	do.	do.	$1\frac{1}{2}'' \times \frac{1}{4}''$ $1\frac{1}{4}''$	do.	do.
5′ 3″	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1''$	do.	do.	do.	do.	$1\frac{1}{2}'' \times \frac{1}{4}''$ $1\frac{1}{4}''$	do.	do.	$1\frac{1}{2}'' \times \frac{3}{8}''$ $1\frac{1}{4}''$
5′ 6″	do.	do.	do.	do.	do.	do.	do.	$1\frac{1}{2}'' \times \frac{3}{8}''$ $1\frac{1}{4}''$	$1\frac{1}{2}'' \times \frac{3}{8}''$ $1\frac{3}{8}''$
5′ 9″	do.	do.	do.	do.	$1\frac{1}{2}'' \times \frac{1}{4}''$ $1\frac{1}{4}''$	do.	do.	$1\frac{1}{2}'' \times \frac{3}{8}''$ $1\frac{3}{8}''$	do.

The dimensions of each limb of the strap are given *above*, and the diameter of the bolt *below*, in each case. The straps at the King-post head and foot may be the same as those shown in the Table, and the bolts for these straps may be $\frac{1}{4}$-inch less than those shown in the Table; no bolt, however, being less than $\frac{1}{2}$-inch diameter.

STRAP AND BOLT AT FOOT OF PRINCIPAL RAFTER—*(concluded)*.

DOUBLE ALLAHABAD TILING.

King-Post Trusses of all kinds of Timber.

Clear internal Spans.

Distance apart of trusses.	10′	12′	14′	16′	18′	20′	22′	24′	26′
6′ 0″	1¼″ × ¼″ 1″	1¼″ × ¼″ 1″	1¼″ × ¼″ 1⅛″	1¼″ × ¼″ 1⅛″	1½″ × ¼″ 1¼″	1½″ × ¼″ 1¼″	1½″ × ⅜″ 1¼″	1½″ × ⅜″ 1⅝″	1½″ × ⅜″ 1⅜″
6′ 3″	do.	do.	do.	do.	do.	do.	1½″ × ⅜″ 1⅜″	do.	do.
6′ 6″	do.	do.	do.	1½″ × ¼″ 1¼″	do.	1½″ × ⅜″ 1¼″	do.	1½″ × ⅜″ 1½″	1½″ × ⅜″ 1½″
6′ 9″	do.	1¼″ × ¼″ 1⅛″	do.	do.	do.	1½″ × ⅜″ 1⅜″	do.	do.	do.
7′ 0″	do.	do.	do.	do.	do.	do.	1½″ × ⅜″ 1½″	do.	1½″ × ⅜″ 1⅜″
7′ 3″	do.	do.	1½″ × ¼″ 1¼″	do.	1½″ × ⅜″ 1¼″	do.	do.	do.	do.
7′ 6″	do.	do.	do.	do.	1½″ × ⅜″ 1⅜″	1½″ × ⅜″ 1½″	do.	do.	1¾″ × ⅜″ 1⅝″
7′ 9″	do.	do.	do.	1½″ × ⅜″ 1¼″	do.	do.	do.	1½″ × ⅜″ 1⅝″	do.
8′ 0″	do.	do.	do.	do.	do.	do.	do.	do.	do.

The dimensions of each limb of the strap are given *above*, and the diameter of the bolt *below*, in each case. The straps at the King-post head and foot may be the same as those shown in the Table, and the bolts for these straps may be ⅛-inch less than those shown in the Table; no bolt, however, being less than ½-inch diameter.

STRAP AND BOLT AT FOOT OF PRINCIPAL RAFTER.

SINGLE ALLAHABAD TILING.

King-Post Trusses of all kinds of Timber.

Clear internal Spans.

Distance apart of trusses.	10′	12′	14′	16′	18′	20′	22′	24′	26′
4′ 0″	1″ × ¼″ ⅝″	1″ × ¼″ ⅝″	1″ × ¼″ ⅝″	1″ × ¼″ ⅝″	1″ × ¼″ ¾″	1″ × ¼″ ¾″	1″ × ¼″ ¾″	1″ × ¼″ ¾″	1″ × ¼″ ⅞″
4′ 3″	do.	do.	do.	do.	do.	do.	do.	do.	1″ × ¼″ 1″
4′ 6″	do.	do	do.	1″ × ¼″ ¾″	do.	do.	do.	do.	do.
4′ 9″	do.	do.	1″ × ¼″ ¾″	do.	do.	do.	do.	1″ × ¼″ 1″	do.
5′ 0″	do.	do.	do.	do.	do.	do.	1″ × ¼″ 1″	do.	do.
5′ 3″	do.	do.	do.	do.	do.	do.	do.	do.	1⅛″ × ¼″ 1⅛″
5′ 6″	do.	do.	do.	do.	do.	1″ × ¼″ 1″	do.	do.	do.
5′ 9″	do.	1″ × ¼″ ¾″	do.	do.	do.	do.	do.	1⅛″ × ¼″ 1⅛″	do.

The dimensions of each limb of the strap are given *above*, and the diameter of the bolt *below*, in each case. The straps at the King-post head and foot may be the same as those shown in the Table, and the bolts for these straps may be ⅛-inch less than those shown in the Table; no bolt, however, being less than ½-inch diameter.

STRAP AND BOLT AT FOOT OF PRINCIPAL RAFTER—*(concluded)*.

SINGLE ALLAHABAD TILING.

King-Post Trusses of all kinds of Timber.

Clear internal Spans.

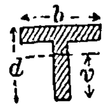
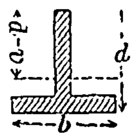
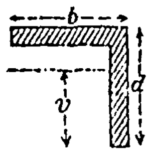
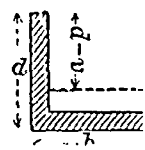
Distance apart of trusses.	10′	12′	14′	16′	18′	20′	22′	24′	26′
6′ 0″	$1'' \times \frac{1}{4}''$ $\frac{5}{8}''$	$1'' \times \frac{1}{4}''$ $\frac{7}{8}''$	$1'' \times \frac{1}{4}''$ $\frac{7}{8}''$	$1'' \times \frac{1}{4}''$ $\frac{7}{8}''$	$1'' \times \frac{1}{4}''$ $1''$	$1'' \times \frac{1}{4}''$ $1''$	$1'' \times \frac{1}{4}''$ $1''$	$1\frac{1}{8}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$	$1\frac{1}{8}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$
6′ 3″	do.	do.	do.	do.	do.	do.	$1\frac{1}{8}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$	do.	do.
6′ 6″	do.	do.	do.	do.	do.	do.	do.	do.	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$
6′ 9″	$1'' \times \frac{1}{4}''$ $\frac{7}{8}''$	do.	do.	$1'' \times \frac{1}{4}''$ $1''$	do.	$1\frac{1}{8}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$	do.	do.	do.
7′ 0″	do.	do.	do.	do.	do.	do.	do.	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$	do.
7′ 3″	do.	do.	do.	do.	do.	do.	do.	do.	do.
7′ 6″	do.	do.	do.	do.	$1\frac{1}{8}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$	do.	do.	do.	do.
7′ 9″	do.	do.	$1'' \times \frac{1}{4}''$ $1''$	do.	do.	do.	$1\frac{1}{4}'' \times \frac{1}{4}''$ $1\frac{1}{8}''$	do.	$1\frac{1}{2}'' \times \frac{1}{4}''$ $1\frac{1}{4}''$
8′ 0″	do.	do.	do.	do.	do.	do.	do.	do.	do.

The dimensions of each limb of the strap are given *above*, and the diameter of the bolt *below*, in each case. The straps at the King-post head and foot may be the same as those shown in the Table, and the bolts for these straps may be ½-inch less than those shown in the Table; no bolt, however, being less than ½-inch diameter.

Table of Strength of T *and* ⅂*-iron, and rolled steel.*

L = Span in feet.
I = Moment of Inertia.
v = Distance of neutral axis from the extreme edge of tension flange.
K = Co-efficient for each Section (*see* Table).
W = Total safe load in lbs. distributed over span including weight of iron.

Then for iron $W = \frac{K}{L}$. For steel $W = \frac{5}{4} \times \frac{K}{L}$. (Factor of safety is 4).

Dimensions of Section, inches.			Values of		Values of K for different Sections and Positions.			
Breadth b.	Depth d.	Thickness.	I.	v or $d-v$.				
4½	4½	½	8·0738	3·1912	18,891	15,113	14,168	11,335
4	6	½	17·3950	4·0132	32,364	25,891	24,273	19,418
4	5	½	10·4562	3·4265	22,785	18,228	17,089	13,671
4	4	½	5·5616	2·8167	14,743	11,794	11,057	8,846
4	3	½	2·4235	2·1731	8,327	6,662	6,245	4,996
4	6	⅜	13·4690	4·0593	24,775	19,820	18,581	14,865
3½	3½	½	3·6350	2·4423	11,113	8,890	8,335	6,668
3½	3½	⅜	2·8651	2·4870	8,602	6,882	6,451	5,161
3	6	½	15·6988	3·8088	30,776	24,621	23,082	18,466
3	5	½	9·4531	3·2500	21,718	17,374	16,288	13,031
3	4	½	5·0485	2·6731	14,102	11,282	10,576	8,461
3	3	½	2·2164	2·0682	8,002	6,401	6,001	4,801
3	3	⅜	1·7597	2·1125	6,220	4,976	4,665	3,732
2½	2½	½	1·2274	1·6944	5,409	4,327	4,057	3,245
2½	2½	⅜	·9839	1·7382	4,226	3,381	3,169	2,536
2½	2½	5/16	·8486	1·7604	3,599	2,879	2,699	2,159
2½	2½	¼	·7031	1·7839	2,945	2,356	2,209	1,767
2	2	½	·5900	1·3214	3,334	2,667	2,500	2,000
2	2	⅜	·4791	1·3642	2,622	2,098	1,966	1,573
2	2	5/16	·4162	1·3861	2,242	1,794	1,681	1,345
2	2	¼	·3476	1·4083	1,843	1,474	1,382	1,106
1½	1½	⅜	·1867	·9911	1,407	1,126	1,055	844
1½	1½	5/16	·1639	1·0124	1,209	967	907	725
1½	1½	¼	·1385	1·0341	1,600	800	750	600
1½	1½	3/16	·1100	1·0562	778	622	583	467
1½	1½	⅛	·0778	1·0788	538	430	403	323

For values of I and K in sections similar to those given above; if I_1, K_1, and d_1 be the values for the required section; then $I_1 = I\frac{d_1^4}{d^4}$; and $K_1 = K\frac{d_1^3}{d^3}$. *Example.*—Find I_1 and K_1 for 4″ × 4″ × ⅝″. I and K for

$2'' \times 2'' \times \frac{5}{16}'' = \cdot41625$ and 2242 respectively. Therefore $I_1 = \cdot41625 \times \frac{256}{16} = 6\cdot66$; and $K_1 = 2242 \times \frac{64}{8} = 17936$.

Old rails.

For an Oudh and Rohilkhand Rail—60 lbs. per yard.

$I = 14\cdot45, \quad d - v = 2\cdot15, \quad K = 40146.$

For a Rajputana-Malwa Rail—40 lbs per yard.

$I = 5\cdot7433, \quad d - v = 1\cdot725, \quad K = 19946.$

For section of above rails *see Plate* IX.

Table of Strength of Rolled Iron and Steel Beams.

Safe strain for iron = 4 tons per square inch in compression.

W = safe load uniformly distributed over beam supported at both ends, including weight of beam, in *tons*.

L = clear internal span between supports, in feet.

K = co-efficient for each section (*see* Table).

Then for iron $K = W \times L$, for steel $\frac{5}{4} K = W \times L$.

Rule.—Multiply weight to be supported by each beam (W) by clear span in feet (L) to give K. Any iron beam having this value of K in the Table below may be used, or any rolled steel beam having K $\frac{4}{5}$ths of this value.

Dimensions of Section, in inches.		Weight of beam in lbs. per foot run.	K.	Dimensions of Section, in inches.		Weight of beam in lbs. per foot run.	K.
Depth.	Breadth.			Depth.	Breadth.		
20	$7\frac{1}{2}$	89	439	7	$3\frac{3}{4}$	16	27
18	7	75	341	$6\frac{1}{4}$	$3\frac{1}{2}$	18	28
16	6	62	241	6	5	25	39
16	5	50	185	6	$4\frac{1}{2}$	20	30
15	6	59	219	6	3	16	22
15	5	42	147	6	3	13	18
14	6	57	198	6	2	12	15
14	6	46	162	$5\frac{1}{2}$	2	10·5	13
13	5	41·5	123	$5\frac{1}{4}$	$1\frac{1}{2}$	9	9
12	6	54	164	5	5	24	32
12	6	44	140	5	$4\frac{1}{2}$	22	29
12	5	32	98	5	$4\frac{3}{16}$	19	24

Rules for Guidance in Calculations for Steel Girders.

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1. The following Formulæ, Tables and Constants are to be used in future, in lieu of those in the Military Works Handbook, for calculating rolled steel girders of English manufacture.

2. The Tables and Constants are arranged to give a limiting stress of $7\frac{1}{2}$ tons per square inch for mild steel. This is considerably higher than the stress allowed for in the Tables in the Handbook, and it is to be distinctly understood that the higher stress is to be used only in the case of girders obtained on indent from England; or of girders purchased locally, which are of English manufacture, and which are guaranteed to bear an ultimate stress of from 27 to 32 tons per square inch.

3. Floor girders, the ends of which are built into the walls, may be treated as fixed beams.

Purlins which are in continuous lengths, or firmly connected by fish-plates, may also be treated as fixed beams.

4. The girders entered in the Tables are the British Standard Sections of Rolled Steel Beams, and these sections only should in future be indented for.

The constants for load and deflection of girders not in the Table can readily be obtained from their moments of inertia, by the formulæ given in the Appendix.

No. 210—500.

TABLE OF ROLLED STEEL JOISTS.

Standard Sections.

With particulars of Sections and Constants for Load and Deflection, with a Limiting Stress of 7·5 tons per square inch.

CASE I., { Condition of joist .... Supported at both ends.
Arrangement of load............ Dead, uniformly distributed, weight of joist included.

Section, in inches.	Weight in lbs. per lineal foot.	Thickness of Web, in inches.	Moment of Inertia, quartic inches.	CONSTANTS. K. For Load $W < \frac{K}{L}$	K_1. For Deflection $\frac{WL^2}{100} < K_1$.
24 × 7½	100	·60	2654	1105·83	368·61
20 × 7½	89	·60	1670	835·00	231·94
18 × 7	75	·55	1149	638·33	159·58
16 × 6	62	·55	725·7	453·56	100·79
15 × 6	59	·50	628·9	419·26	87·34
15 × 5	42	·42	428	285·33	59·44
14 × 6	57	·50	532·9	380·64	74·01
14 × 6	46	·40	440·5	314·64	61·18
12 × 6	54	·50	375·5	312·90	52·15
12 × 6	44	·40	315·3	262·75	43·79
12 × 5	32	·35	220	183·33	30·55
10 × 8	70	·60	344·9	344·90	47·90
10 × 6	42	·40	211·5	211·50	29·375
10 × 5	30	·36	145·6	145·60	20·222
9 × 7	58	·55	229·5	255·00	31·875
9 × 4	21	·30	81·1	90·11	11·263
8 × 6	35	·44	110·5	138·12	15·347
8 × 5	28	·35	89·32	111·65	12·405
8 × 4	18	·28	55·69	69·61	7·734
7 × 4	16	·25	39·21	56·01	5·445
6 × 5	25	·41	43·61	72·68	6·057
6 × 4½	20	·37	34·62	57·70	4·808
6 × 3	12	·26	20·21	33·68	2·807
5 × 4½	18	·29	22·69	45·38	3·151
5 × 3	11	·22	13·61	27·22	1·890
4¾ × 1¾	6·5	·18	6·73	14·17	·934
4 × 3	9·5	·22	7·52	18·80	1·044
4 × 1¾	5	·17	3·668	9·15	·508
3 × 3	8·5	·20	3·787	12·62	·525
3 × 1½	4	·16	1·659	5·53	·230

To use the foregoing Table—

(*i*). To select a joist for a given external load (*i.e.*, load exclusive of weight of joist) and a given span :—

Multiply the load (*in tons*) by the clear span (*in feet*) and select a section from the Table, against which the constant for load "K" is slightly higher than the result.

The weight of the joist should then be added to the external load and the section selected tried, as shown in (*ii*) and (*iii*) below, for load and deflection.

(*ii*). To find the load for a given section of joist with a given span :—

Divide the constant for load "K" by the span (*in feet*).

The quotient is the safe distributed load (*in tons*), including the weight of the joist.

FOR LOAD—

$$\frac{K}{L} \times c \text{ must be } \left\{ \begin{array}{c} \text{equal to} \\ \text{or} \\ \text{greater than} \end{array} \right\} W \text{ tons.}$$

(*iii*). To determine whether for a given section of joist and a given span, the resultant deflection caused by a given load, including weight of girder, will be greater than the maximum deflection permissible, *viz.*, $\frac{1}{30}$ inch per foot run of span.

Multiply the total weight (*in tons*) by the square of the span (*in feet*) and divide by 100.

If the quotient is equal to or less than the constant for deflection, it will show that the maximum deflection permissible has not been exceeded.

FOR DEFLECTION—

$$\frac{W \textit{ tons} \times L^2}{100} \times c_1 \text{ must be } \left\{ \begin{array}{c} \text{equal to} \\ \text{or} \\ \text{less than} \end{array} \right\} K_1.$$

N.B.—In cases where it is considered that a deflection of $\frac{1}{30}$ inch per foot run is excessive, (as for instance in very long spans, or for other reasons), the following formula for deflection must be used :—

FOR DEFLECTION—

$$\frac{W \textit{ tons} \times L^3}{4000 \times D^1} \times c_1 \text{ must be } \left\{ \begin{array}{c} \text{equal to} \\ \text{or} \\ \text{less than} \end{array} \right\} K_1$$

where D^1 is the maximum deflection (*in inches*) considered advisable.

Note.—c and c_1 in (*ii*) and (*iii*) above are the constants for load and deflection due to different conditions of the girders, and will be found on the following page for Cases II. to XII.

Tables for facilitating calculations for long wrought-iron columns or struts of L *or* T*-iron (founded on Formula VI.)*

TABLE I.

Dimensions of Section, in inches.	Area of Section, in sq. inches. S.	h = LEAST TRANSVERSE DIMENSION, IN INCHES.		Dimensions of Section, in inches.	Area of Section, in sq. inches. S.	h = LEAST TRANSVERSE DIMENSION, IN INCHES.	
		T-Iron.	L-Iron.			T-Iron.	L-Iron.
$4\frac{1}{2} \times 4\frac{1}{2} \times \frac{1}{2}$	4·250	4·25	3·54	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{2}$	2·250	2·46	2·12
$4 \times 6 \times \frac{1}{2}$	4·750	3·96	3·64	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{3}{8}$	1·734	2·40	2·03
$4 \times 5 \times \frac{1}{2}$	4·250	3·91	3·46	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{5}{16}$	1·485	2·38	1·99
$4 \times 4 \times \frac{1}{2}$	3·750	3·80	3·18	$2\frac{1}{2} \times 2\frac{1}{2} \times \frac{1}{4}$	1·187	2·35	1·94
$4 \times 3 \times \frac{1}{2}$	3 250	3·00	2·73	$2 \times 2 \times \frac{1}{2}$	1·750	2·00	1·77
$4 \times 6 \times \frac{3}{8}$	3·609	3·92	3·57	$2 \times 2 \times \frac{3}{8}$	1·359	1·96	1·68
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{1}{2}$	3·250	3·35	2·83	$2 \times 2 \times \frac{5}{16}$	1·152	1·93	1·64
$3\frac{1}{2} \times 3\frac{1}{2} \times \frac{3}{8}$	2·484	3·30	2·74	$2 \times 2 \times \frac{1}{4}$	·937	1·90	1·59
$3 \times 6 \times \frac{1}{2}$	4·250	3·00	2·94	$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{8}$	·984	1·50	1·33
$3 \times 5 \times \frac{1}{2}$	3·750	3·00	2·87	$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{5}{16}$	·840	1·48	1·28
$3 \times 4 \times \frac{1}{2}$	3·250	2·99	2·73	$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$	·687	1·45	1·24
$3 \times 3 \times \frac{1}{2}$	2·750	2·91	2·47	$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{16}$	·527	1·43	1·19
$3 \times 3 \times \frac{3}{8}$	2·109	2·85	2·39	$1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{8}$	·359	1·40	1·15

TABLE II.

$$R = \frac{\text{Length}}{\text{least diameter}} \text{ ends fixed.}$$

$R' =$ " " rounded.

c_1 = safe intensity of pressure per square inch, in lbs.

R	R′	c_1	R	R′	c_1	R	R′	c_1	R	R′	c_1
10	...	8,670	28	14	7,103	46	23	5,255	64	32	3,787
12	...	8,550	30	15	6,892	48	24	5,067	66	33	3,653
14	...	8,411	32	16	6,679	50	25	4,887	68	34	3,526
16	...	8,254	34	17	6,467	52	26	4,713	70	35	3,402
18	...	8,086	36	18	6,256	54	27	4,543	72	36	3,284
20	10	7,905	38	19	6,048	56	28	4,381	74	37	3,172
22	11	7,714	40	20	5,844	58	29	4,224	76	38	3,062
24	12	7,517	42	21	5,642	60	30	4,072	78	39	2,939
26	13	7,311	44	22	5,445	62	31	3,929	80	40	2,856

Example.—Compression on strut = 13,500 lbs.; length of strut = 86 inches. The strut is to be of T-iron; the ends are fixed. Assume $h = 2{\cdot}60$. Then $R = \frac{86}{2{\cdot}60} = 33$. From Table II., $c_1 = 6467$. Then $S = \frac{13500}{6467} = 2{\cdot}10$. From Table I. it is seen that a section $3'' \times 3'' \times \frac{3}{8}''$ satisfies the area of section required with the assumed value of h. The strut should therefore be made of this size.

For steel: multiply the values of c_1 by $\frac{5}{4}$ and conduct calculation as above.

Table of safe distributed load in tons on rolled steel beams supported at both ends. Safe compression is taken at 5 tons per square inch, or Factor of Safety is 4.

Dimensions of Section. Depth.	Breadth.	Weight of beam in lbs. per foot run.	CLEAR SPAN IN FEET. 2′	4′	6′	8′	10′	12′
7	$3\frac{3}{4}$	18	...	9·97	6·61	4·94	3·92	3·23
7	$3\frac{3}{4}$	16	...	8·48	5·62	4·19	3·33	2·74
$6\frac{1}{4}$	$3\frac{1}{2}$	18	...	8·72	5·78	4·31	3·42	...
6	5	25	...	12·15	8·05	6·85	4·76	...
6	$4\frac{1}{2}$	20	...	9·34	6·20	4·62	3·66	...
6	3	16	...	6·86	4·54	3·38	2·68	...
6	3	13	...	5·60	3·72	2·76	2·19	...
6	2	12	...	4·67	3·10	2·30	1·82	...
$5\frac{1}{2}$	2	10·5	...	4·04	2·68	2·0	1·59	...
$5\frac{1}{4}$	$1\frac{1}{2}$	9	...	2·79	1·86	1·38	...	...
5	5	24	...	9·96	6·60	4·92	...	...
5	$4\frac{1}{2}$	22	...	9·02	5·98	4·45	...	...
5	$4\frac{3}{16}$	19	...	7·46	4·95	3·68	...	...
5	3	15	...	5·28	3·50	2·61	...	...
5	3	11	...	4·67	3·10	2·30	...	...
$4\frac{3}{4}$	$1\frac{3}{4}$	10	...	2·97	1·95	1·44	...	...
$4\frac{3}{4}$	$1\frac{3}{4}$	6·5	...	2·25	1·49	1·10	...	...
$4\frac{5}{8}$	3	14	...	4·67	3·09	2·29	...	...
4	3	12	7·49	4·23	2·48	...	...	...
4	3	9·5	6·12	3·04	2·01	...	...	...
4	$1\frac{3}{4}$	8	4·29	2·14	1·41	...	...	...
4	$1\frac{3}{4}$	5	3·02	1·50	1·00	...	...	...
$3\frac{1}{2}$	3	10·5	5·58	2·77	1·83	...	...	...
$3\frac{1}{2}$	$1\frac{1}{2}$	6	2·76	1·37	·90	...	...	...
3	3	10	4·67	2·32	...	...	...	...
3	$1\frac{1}{4}$	4	1·00	·49	...	...	...	...

N.B.—The depth of rolled steel beams should not be less than $\frac{1}{20}$th of the span, or they will deflect unduly.

Dimensions of Iron bars, &c., for Trusses of the Design shown in Plate II. of Handbook, supporting Double Allahabad pattern tiling.

Distance apart, Feet.	Weight, lbs.					Dimensions of bars.					Number of rivets ¾" diameter.				Remarks.
	A_1	A_3	C_1	C_2	C_3	A_1	A_3	C_1	C_2	C_3	A_3	C_1	C_2	C_3	
Span	22 feet.						Double 2¼" × ¼" bars with 1" diameter distance pieces								
6	5,440	12,020	2,450	10,880	5,110	6,530	3" × 3" × ⅜"	2 dist. pieces	3½" × ⅜"	2¼" × ⅜"	2½" × ⅜"	1	4	2	3	
6½	5,890	13,020	2,650	11,790	5,540	7,070	do.		do.	do.	do.	1	4	2	3	
7	6,350	14,020	2,860	12,690	5,970	7,620	do.		3¾" × ⅜"	do.	2¾" × ⅜"	1	4	2	3	
7½	6,800	15,030	3,060	13,600	6,390	8,160	3½" × 3½" × ⅜"		4" × ⅜"	do.	do.	1	5	3	3	
8	7,250	16,030	3,260	14,510	6,820	8,700	do.		4¼" × ⅜"	2½" × ⅜"	3" × ⅜"	2	5	3	3	
8½	7,710	17,030	3,470	15,410	7,240	9,250	do.	3 dist. pieces	4½" × ⅜"	do.	do.	2	5	3	3	
9	8,160	18,030	3,670	16,320	7,670	9,790	do.		4¾" × ⅜"	2¾" × ⅜"	3¼" × ⅜"	2	6	3	4	
9½	8,610	19,040	3,870	17,230	8,100	10,340	3½" × 3½" × ½"		4" × ½"	2¼" × ½"	2¾" × ½"	1	5	2	3	
10	9,070	20,040	4,080	18,130	8,520	10,880	do.		do.	do.	do.	1	5	3	3	
10½	9,520	21,040	4,280	19,040	8,950	11,420	do.		4¼" × ½"	2½" × ½"	3" × ½"	2	5	3	3	
11	9,970	22,040	4,490	19,950	9,370	11,970	do.		4½" × ½"	do.	do.	2	5	3	3	
Span	24 feet.														
6	5,880	13,000	2,650	11,760	5,530	7,060	3" × 3" × ⅜"	2 dist. pieces	3½" × ⅜"	2¼" × ⅜"	2½" × ⅜"	1	4	2	3	
6½	6,370	14,080	2,870	12,740	5,990	7,650	3½" × 3½" × ⅜"		3¾" × ⅜"	do.	2¾" × ⅜"	1	4	2	3	
7	6,860	15,160	3,090	13,720	6,450	8,240	do.		4" × ⅜"	do.	do.	1	5	3	3	
7½	7,350	16,250	3,310	14,700	6,910	8,820	do.		4¼" × ⅜"	2½" × ⅜"	3" × ⅜"	2	5	3	3	
8	7,840	17,330	3,530	15,680	7,370	9,410	do.		4½" × ⅜"	do.	do.	2	5	3	3	
8½	8,330	18,410	3,750	16,660	7,830	10,000	3½" × 3½" × ½"		3¾" × ½"	2¼" × ½"	2¾" × ½"	1	4	2	3	
9	8,820	19,500	3,970	17,640	8,290	10,590	do.	3 dist. pieces	4" × ½"	do.	do.	1	5	2	3	
9½	9,310	20,580	4,190	18,620	8,750	11,180	do.		4¼" × ½"	2½" × ½"	do.	1	5	3	3	
10	9,800	21,660	4,410	19,600	9,210	11,760	do.		do.	do.	3" × ½"	2	5	3	3	
10½	10,290	22,750	4,630	20,580	9,670	12,350	do.		4½" × ½"	do.	do.	2	5	3	3	
11	10,780	23,830	4,850	21,560	10,130	12,940	4" × 4" × ½"		4¾" × ½"	2¾" × ½"	3¼" × ½"	2	6	3	4	

Wrought-iron.

In calculating iron trusses which are geometrically similar to those described in Examples V., VI. and VII., the following constants may be made use of :—

I.—Truss similar to that described in Example V., page 148 (*Plate* II.).	Compression of	A 1, ...	2·21 W.
	„	A 2, ...	2 W.
	„	A 3, ...	·45 W.
	Tension	C 1, ...	2 W.
	„	C 2, ...	·94 W.
	„	C 3, ...	1·2 W.
II.—Truss similar to that described in Example VI., page 152 (*Plate* III.).	Compression of	A 1, ...	2·46 W.
	„	A 2, ...	2·3 W.
	„	A 3, ...	1·75 W.
	„	A 4, ...	·3 W.
	„	A 5, ...	·45 W.
	Tension	C 1, ...	2·22 W.
	„	C 2, ...	1·8 W.
	„	C 3, ...	1·23 W.
	„	C 4, ...	·45 W.
	„	C 5, ...	·7 W.
III.—Truss similar to that described in Example VII., page 158, (*Plate* IV.).	Compression of	A 1, ...	2·8 W.
	„	A 2, ...	2·7 W.
	„	A 3, ...	2 6 W.
	„	A 4, ...	2·5 W.
	„	{A 5, A 7,}	·23 W.
	„	A 6, ...	·45 W.
	Tension	C 1, ...	2·53 W.
	„	C 2, ...	2·17 W.
	„	C 3, ...	1·22 W.
	„	C 4, ...	1·03 W.
	„	C 5, ...	1·43 W.
	„	{C 6, C 7,}	·362 W.

In all cases W equals half the weight of one truss and its load, and may be taken either in lbs. or tons.

Foul Pipes.

Head of water consumed by friction in pipes 100 feet long calculated by Fanning's formula with varying co-efficients for foul pipes.

$$H = \frac{G^2 \times m \times L}{5{\cdot}5767 \times d^5}$$

Gallons per minute.	Diameter of pipe in inches.					
	1	1½	2	2½	3	3½
	Value of *m*.					
	·015	·0145	·014	·0135	·013	·0125
	Head of water in feet.					
1	·26898	·03424	·00785	·00248	·00096	·00043
2	1·07590	·13696	·03138	·00992	·00384	·00171
3	2·42079	·30816	·07061	·02231	·00863	·00384
4	4·30362	·54784	·12552	·03966	·01535	·00683
5	6·72441	·85600	·19613	·06197	·02398	·01067
6	9·68314	1·23263	·28242	·08924	·03454	·01536
7	13·17983	1·67775	·38441	·12147	·04701	·02091
8	17·21448	2·19135	·50209	·15865	·06140	·02731
9	21·78707	2·77342	·63545	·20079	·07771	·03457
10	26·89762	3·42398	·78451	·24789	·09594	·04268
11	32·54612	4·14302	·94926	·29995	·11608	·05164
12	38·73257	4·93053	1·12969	·35696	·13815	·06145
13	45·45698	5·78653	1·32582	·41893	·16213	·07212
14	52·71934	6·71100	1·53764	·48586	·18803	·08365
15	60·51965	7·70396	1·76515	·55775	·21585	·09602
16	68·85791	8·76539	2·00835	·63460	·24559	·10925
17	77·73412	9·89530	2·26723	·71640	·27725	·12334
18	87·14829	11·09370	2·54181	·80316	·31083	·13827
19	97·10041	12·36057	2·83208	·89488	·34633	·15406
20	107·59048	13·69592	3·13804	·99156	·38374	·17071
21		15·09975	3·45969	1·09320	·42307	·18820
22		16·57206	3·79703	1·19979	·46433	·20655
23		18·11285	4·15006	1·31134	·50750	·22576
24		19·72212	4·51878	1·42785	·55259	·24582
25		21·39988	4·90319	1·54931	·59959	·26673
26		23·14610	5·30329	1·67574	·64852	·28849
27		24·96081	5·71908	1·80712	·69937	·31111
28		26·84400	6·15056	1·94346	·75213	·33458
29		28·79567	6·59773	2·08476	·80681	·35891
30		30·81582	7·06059	2·23101	·86342	·38409
31		32·90445	7·53914	2·38222	·92194	·41012
32		35·06156	8·03338	2·53839	·98237	·43701
33		37·28714	8·54331	2·69952	1·04473	·46475
34		39·58121	9·06894	2·86561	1·10901	·49334
35		41·94376	9·61025	3·03665	1·17520	·52279
36		44·37478	10·16725	3·21265	1·24332	·55309
37		46·87429	10·73994	3·39361	1·31335	·58424
38		49·44227	11·32832	3·57953	1·38530	·61625

Dimensions of Steel bars, &c., for Trusses of the Design shown in Plate II. of Handbook, supporting Double Allahabad pattern tiling.

Distance apart, Feet.	Weight, lbs.					Dimensions of bars.					Number of rivets ¾" diameter.				Remarks.
	A_1	A_3	C_1	C_2	C_3	A_1	A_3	C_1	C_2	C_3	A_3	C_1	C_2	C_3	
Span	22 feet														
6	5,440	12,020	2,450	10,880	5,110	6,580	2½" × 2½" × ⅜"	Double 2¼" × ¼" bars with 1" diameter distance pieces +3 dist. pieces+ 2 dist. pieces+ +3 dist. pieces +2 dist. pieces+	3" × ⅜"	2¼" × ⅜"	2¼" × ⅜"	1	3	2	2	
6½	5,890	13,020	2,650	11,790	5,540	7,070	do.		do.	2¼" × ⅜"	do.	1	3	2	2	
7	6,350	14,020	2,860	12,690	5,970	7,620	3" × 3" × ⅜"		3¼" × ⅜"	do.	do.	1	4	2	2	
7½	6,800	15,030	3,060	13,600	6,390	8,160	do.		3½" × ⅜"	do.	2½" × ⅜"	1	4	2	3	
8	7,250	16,030	3,260	14,510	6,820	8,700	do.		3¾" × ⅜"	do.	do.	1	4	2	3	
8½	7,710	17,030	3,470	15,410	7,240	9,250	do.		do.	do.	2¾" × ⅜"	1	4	2	3	
9	8,160	18,030	3,670	16,320	7,670	9,790	do.		4" × ⅜"	do.	do.	1	5	2	3	
9½	8,610	19,040	3,870	17,230	8,100	10,340	3½" × 3¼" × ⅜"		4¼" × ⅜"	2½" × ⅜"	do.	1	5	3	3	
10	9,070	20,040	4,080	18,130	8,520	10,880	do.		do.	do.	3" × ⅜"	2	5	3	3	
10½	9,520	21,040	4,280	19,040	8,950	11,420	do.		4½" × ⅜"	do.	do.	2	5	3	3	
11	9,970	22,040	4,490	19,950	9,370	11,970	do.		4¾" × ⅜"	2¾" × ⅜"	3¼" × ⅜"	2	6	3	4	
Span	24 feet														
6	5,880	13,000	2,650	11,760	5,530	7,060	3" × 3" × ⅜"		3" × ⅜"	2¼" × ⅜"	2¼" × ⅜"	1	3	2	2	
6½	6,370	14,080	2,870	12,740	5,990	7,650	do.		3¼" × ⅜"	do.	do.	1	4	2	2	
7	6,860	15,160	3,090	13,720	6,450	8,240	do.		3½" × ⅜"	do.	2½" × ⅜"	1	4	2	3	
7½	7,350	16,250	3,310	14,700	6,910	8,820	do.		3¾" × ⅜"	do.	do.	1	4	2	3	
8	7,840	17,330	3,530	15,680	7,370	9,410	3½" × 3½" × ⅜"		do.	do.	2¾" × ⅜"	1	4	2	3	
8½	8,330	18,410	3,750	16,660	7,830	10,000	do.		4" × ⅜"	do.	do.	1	5	2	3	
9	8,820	19,500	3,970	17,640	8,290	10,590	do.		4¼" × ⅜"	2½" × ⅜"	3" × ⅜"	1	5	3	3	
9½	9,310	20,580	4,190	18,620	8,750	11,180	do.		4½" × ⅜"	do.	do.	1	5	3	3	
10	9,800	21,660	4,410	19,600	9,210	11,760	do.		do.	2¾" × ⅜"	do.	2	5	3	3	
10½	10,290	22,750	4,630	20,580	9,670	12,350	3½" × 3½" × ½"		3¾" × ½"	2¼" × ½"	2¾" × ½"	1	4	2	3	
11	10,780	23,830	4,850	21,560	10,130	12,940	do.		4" × ½"	do.	do.	1	5	2	3	

Steel.

FOUL PIPES—*(concluded)*.

Gallons per minute.	Diameter of pipe in inches. 1	1½	2	2½	3	3½
	Value of m. ·015	·0145	·014	·0135	·013	·0125
	Head of water in feet.					
83				17·07714	6·60896	2·93998
84				17·49112	6·76917	3·01125
85				17·91005	6·93130	3·08338
86				18·33394	7·09535	3·15635
87				18·76279	7·26132	3·23018
88				19·19660	7·42921	3·30487
89				19·63537	7·59901	3·38041
90				20·07909	7·77074	3·45680
91				20·52777	7·94438	3·53404
92				20·98141	8·11994	3·61214
93				21·44001	8·29742	3·69109
94				21·90356	8·47682	3·77090
95				22·37207	8·65813	3·85155
96				22·84554	8·84137	3·93307
97				23·32397	9·02652	4·01543
98				23·80736	9·21360	4·09865
99				24·29570	9·40259	4·18272
100				24·78900	9·59350	4·26765

SLIGHTLY TUBERCULATED—(*continued*).

Gallons per minute.	Diameter of pipe in inches.				
	3	3½	4	5	6
	Value of m.				
	·00862	·008435	·00825	·007985	·00772
	Head of water in feet.				
36	·82438	·37322	·18723	·05938	·02307
37	·87081	·39425	·19778	·06273	·02437
38	·91852	·41585	·20861	·06616	·02571
39	·96750	·43802	·21974	·06969	·02708
40	1·01775	·46077	·23115	·07331	·02848
41	1·06927	·48410	·24285	·07702	·02993
42	1·12207	·50800	·25484	·08082	·03140
43	1·17614	·53248	·26712	·08472	·03292
44	1·23148	·55753	·27969	·08871	·03447
45	1·28809	·58316	·29255	·09278	·03605
46	1·34597	·60937	·30570	·09695	·03767
47	1·40513	·63615	·31913	·10121	·03933
48	1·46556	·66351	·33286	·10557	·04102
49	1·52726	·69144	·34687	·11001	·04274
50	1·59023	·71996	·36117	·11455	·04451
51	1·65448	·74904	·37576	·11918	·04630
52	1·72000	·77870	·39064	·12389	·04814
53	1·78679	·80894	·40581	·12871	·05001
54	1·85485	·83976	·42127	·13361	·05191
55	1·92418	·87115	·43702	·13860	·05385
56	1·99479	·90311	·45305	·14369	·05583
57	2·06667	·93565	·46938	·14887	·05784
58	2·13982	·96877	·48599	·15413	·05989
59	2·21424	1·00247	·50290	·15950	·06197
60	2·28993	1·03674	·52009	·16495	·06409
61	2·36690	1·07158	·53757	·17049	·06624
62	2·44514	1·10700	·55534	·17613	·06843
63	2·52465	1·14300	·57340	·18186	·07066
64	2·60544	1·17957	·59174	·18767	·07292
65	2·68749	1·21672	·61038	·19359	·07522
66	2·77082	1·25445	·62931	·19959	·07755
67	2·85542	1·29275	·64852	·20568	·07992
68	2·94129	1·33163	·66802	·21187	·08232
69	3·02844	1·37108	·68782	·21814	·08476
70	3·11686	1·41111	·70790	·22451	·08723
71	3·20654	1·45172	·72827	·23097	·08974
72	3·29751	1·49290	·74893	·23753	·09229
73	3·38974	1·53466	·76987	·24417	·09487
74	3·48325	1·57699	·79111	·25091	·09749
75	3·57802	1·61990	·81264	·25773	·10014
76	3·67407	1·66338	·83445	·26465	·10283
77	3·77140	1·70745	·85656	·27166	·10555
78	3·86999	1·75208	·87895	·27876	·10831
79	3·96986	1·79730	·90163	·28596	·11111
80	4·07100	1·84308	·92460	·29324	·11394

Slightly Tuberculated.

Head of water consumed by friction in pipes 100 feet long calculated by Fanning's formula with varying co-efficients for slightly tuberculated pipes.

$$H = \frac{G^2 \times m \times L.}{5{\cdot}5767 \times d^5}$$

Gallons per minute.	Diameter of pipe in inches.				
	3	3½	4	5	6
	Value of *m*.				
	·00862	·008435	·00825	·007985	·00772
	Head of water in feet.				
1	·00064	·00029	·00014	·00005	·00002
2	·00254	·00115	·00058	·00018	·00007
3	·00572	·00259	·00130	·00041	·00016
4	·01018	·00461	·00231	·00073	·00028
5	·01590	·00720	·00361	·00115	·00045
6	·02290	·01037	·00520	·00165	·00064
7	·03117	·01411	·00708	·00225	·00087
8	·04071	·01843	·00925	·00293	·00114
9	·05152	·02333	·01170	·00371	·00144
10	·06361	·02880	·01445	·00458	·00178
11	·07697	·03485	·01748	·00554	·00215
12	·09160	·04147	·02080	·00660	·00256
13	·10750	·04867	·02442	·00774	·00301
14	·12467	·05644	·02832	·00898	·00349
15	·14312	·06480	·03251	·01031	·00401
16	·16284	·07372	·03698	·01173	·00456
17	·18383	·08323	·04175	·01324	·00514
18	·20609	·09331	·04681	·01485	·00577
19	·22963	·10396	·05215	·01654	·00643
20	·25444	·11519	·05779	·01833	·00712
21	·28052	·12700	·06371	·02021	·00785
22	·30787	·13938	·06992	·02218	·00862
23	·33649	·15234	·07642	·02424	·00942
24	·36639	·16588	·08321	·02639	·01025
25	·39756	·17999	·09029	·02864	·01113
26	·43000	·19468	·09766	·03097	·01203
27	·46371	·20994	·10532	·03340	·01298
28	·49870	·22578	·11326	·03592	·01396
29	·53495	·24219	·12150	·03853	·01497
30	·57248	·25918	·13002	·04124	·01602
31	·61129	·27675	·13883	·04403	·01711
32	·65136	·29489	·14794	·04692	·01823
33	·69271	·31361	·15733	·04990	·01939
34	·73532	·33291	·16701	·05297	·02058
35	·77921	·35278	·17627	·05613	·02181

SLIGHTLY TUBERCULATED—(*continued*).

Gallons per minute.	Diameter of pipe in inches.				
	7	8	9	10	12
	Value of *m*.				
	·00752	·00733	·00719	·00706	·00680
	Head of water in feet.				
10	·00080	·00040	·00022	·00013	·00005
20	·00321	·00160	·00087	·00051	·00020
30	·00722	·00361	·00197	·00114	·00044
40	·01284	·00642	·00349	·00203	·00078
50	·02006	·01003	·00546	·00316	·00123
60	·02888	·01444	·00786	·00456	·00176
70	·03931	·01965	·01070	·00620	·00240
80	·05135	·02567	·01397	·00810	·00314
90	·06499	·03249	·01769	·01025	·00397
100	·08023	·04011	·02183	·01266	·00490
110	·09708	·04854	·02642	·01532	·00593
120	·11553	·05776	·03144	·01823	·00706
130	·13559	·06779	·03690	·02139	·00828
140	·15725	·07862	·04279	·02481	·00960
150	·18052	·09025	·04913	·02848	·01103
160	·20539	·10269	·05590	·03241	·01254
170	·23187	·11592	·06310	·03659	·01416
180	·25995	·12996	·07074	·04102	·01588
190	·28964	·14480	·07882	·04570	·01769
200	·32093	·16045	·08734	·05064	·01960
210	·35382	·17689	·09629	·05583	·02161
220	·38832	·19414	·10568	·06127	·02372
230	·42443	·21219	·11550	·06697	·02592
240	·46214	·23105	·12576	·07292	·02823
250	·50145	·25070	·13646	·07912	·03063
260	·54237	·27116	·14760	·08558	·03313
270	·58489	·29242	·15917	·09229	·03572
280	·62902	·31448	·17118	·09925	·03842
290	·67475	·33734	·18362	·10647	·04121
300	·72209	·36101	·19651	·11394	·04410
310	·77103	·38548	·20983	·12166	·04709
320	·82158	·41075	·22358	·12964	·05018
330	·87373	·43682	·23777	·13786	·05336
340	·92748	·46369	·25240	·14635	·05665
350	·98284	·49137	·26747	·15508	·06003
360	1·03981	·51985	·28297	·16407	·06351
370	1·09838	·54913	·29891	·17331	·06709
380	1·15855	·57922	·31528	·18281	·07076
390	1·22033	·61010	·33210	·19255	·07453
400	1·28371	·64179	·34935	·20256	·07840
410	1·34870	·67428	·36703	·21281	·08237
420	1·41529	·70758	·38515	·22332	·08644
430	1·48349	·74167	·40371	·23408	·09061
440	1·55329	·77657	·42271	·24509	·09487
450	1·62470	·81227	·44214	·25636	·09923

SLIGHTLY TUBERCULATED—*(continued)*.

Gallons per minute.	Diameter of pipe in inches.				
	3	$3\frac{1}{2}$	4	5	6
	Value of m.				
	·00862	·008435	·00825	·007985	·00772
	Head of water in feet.				
81	4·17341	1·88945	·94786	·30062	·11680
82	4·27709	1·93639	·97141	·30809	·11970
83	4·38204	1·98391	·99525	·31565	·12264
84	4·48827	2·03200	1·01937	·32330	·12561
85	4·59577	2·08067	1·04379	·33104	·12862
86	4·70454	2·12991	1·06849	·33888	·13167
87	4·81459	2·17974	1·09349	·34680	·13475
88	4·92590	2·23013	1·11877	·35482	·13786
89	5·03849	2·28111	1·14434	·36293	·14101
90	5·15235	2·33265	1·17020	·37113	[illegible]
91	5·26749	2·38478	1·19635	·37943	[illegible]
92	5·38389	2·43748	1·22279	·38781	[illegible]
93	5·50157	2·49076	1·24951	·39629	[illegible]
94	5·62052	2·54461	1·27653	·40486	[illegible]
95	5·74074	2·59904	1·30383	[illegible]	[illegible]
96	5·86223	2·65404	1·33143	[illegible]	[illegible]
97	5·98500	2·70962	1·35931	[illegible]	[illegible]
98	6·10904	2·76578	1·38748	[illegible]	[illegible]
99	6·23435	2·82251	1·41594	[illegible]	[illegible]
100	6·36093	2·87982	1·44469	[illegible]	[illegible]

SLIGHTLY TUBERCULATED—(*continued*).

Gallons per minute.	Diameter of pipe in inches. 7	8	9	10	12
	Value of m.				
	·00752	·00733	·00719	·00706	·00680
	Head of water in feet.				
10	·00080	·00040	·00022	·00013	·00005
20	·00321	·00160	·00087	·00051	·00020
30	·00722	·00361	·00197	·00114	·00044
40	·01284	·00642	·00349	·00203	·00078
50	·02006	·01003	·00546	·00316	·00123
60	·02888	·01444	·00786	·00456	·00176
70	·03931	·01965	·01070	·00620	·00240
80	·05135	·02567	·01397	·00810	·00314
90	·06499	·03249	·01769	·01025	·00397
100	·08023	·04011	·02183	·01266	·00490
110	·09708	·04854	·02642	·01532	·00593
120	·11553	·05776	·03144	·01823	·00706
130	·13559	·06779	·03690	·02139	·00828
140	·15725	·07862	·04279	·02481	·00960
150	·18052	·09025	·04913	·02848	·01103
160	·20539	·10269	·05590	·03241	·01254
170	·23187	·11592	·06310	·03659	·01416
180	·25995	·12996	·07074	·04102	·01588
190	·28964	·14480	·07882	·04570	·01769
200	·32093	·16045	·08734	·05064	·01960
210	·35382	·17689	·09629	·05583	·02161
220	·38832	·19414	·10568	·06127	·02372
230	·42443	·21219	·11550	·06697	·02592
240	·46214	·23105	·12576	·07292	·02823
250	·50145	·25070	·13646	·07912	·03063
260	·54237	·27116	·14760	·08558	·03313
270	·58489	·29242	·15917	·09229	·03572
280	·62902	·31448	·17118	·09925	·03842
290	·67475	·33734	·18362	·10647	·04121
300	·72209	·36101	·19651	·11394	·04410
310	·77103	·38548	·20983	·12166	·04709
320	·82158	·41075	·22358	·12964	·05018
330	·87373	·43682	·23777	·13786	·05336
340	·92748	·46369	·25240	·14635	·05665
350	·98284	·49137	·26747	·15508	·06003
360	1·03981	·51985	·28297	·16407	·06351
370	1·09838	·54913	·29891	·17331	·06709
380	1·15855	·57922	·31528	·18281	·07076
390	1·22033	·61010	·33210	·19255	·07453
400	1·28371	·64179	·34935	·20256	·07840
410	1·34870	·67428	·36703	·21281	·08237
420	1·41529	·70758	·38515	·22332	·08644
430	1·48349	·74167	·40371	·23408	·09061
440	1·55329	·77657	·42271	·24509	·09487
450	1·62470	·81227	·44214	·25636	·09923

SLIGHTLY TUBERCULATED—(*continued*).

Gallons per minute.	Diameter of pipe in inches.				
	7	8	9	10	12
	Value of *m*.				
	·00752	·00733	·00719	·00706	·00680
	Head of water in feet.				
460	1·69771	·84877	·46201	·26788	·10369
470	1·77232	·88607	·48232	·27965	·10825
480	1·84855	·92418	·50306	·29168	·11290
490	1·92637	·96309	·52424	·30396	·11766
500	2·00580	1·00280	·54585	·31649	·12251
510	2·08683	1·04331	·56790	·32928	·12746
520	2·16947	1·08463	·59039	·34232	·13250
530	2·25372	1·12675	·61332	·35561	·13765
540	2·33956	1·16967	·63668	·36916	·14289
550	2·42702	1·21339	66048	·38296	·14823
560	2·51608	1·25791	·68472	·39701	·15367
570	2·60674	1·30324	·70939	·41131	·15921
580	2·69900	1·34937	·73450	·42587	·16485
590	2·79288	1·39630	·76005	·44068	·17058
600	2·88835	1·44403	·78603	·45575	·17641
610	2·98543	1·49257	·81245	·47107	·18234
620	3·08412	1·54191	·83930	·48664	·18837
630	3·18441	1·59205	·86660	·50246	·19449
640	3·28630	1·64299	·89432	·51854	·20072
650	3·38980	1·69473	·92249	·53487	·20704
660	3·49491	1·74728	·95109	·55146	·21346
670	3·60161	1·80063	·98013	·56829	·21998
680	3·70993	1·85478	1·00961	·58538	·22659
690	3·81985	1·90973	1·03952	·60273	·23330
700	3·93137	1·96549	1·06987	·62033	·24011
710	4·04450	2·02205	1·10066	·63818	·24702
720	4·15923	2·07941	1·13188	·65628	·25403
730	4·27556	2·13757	1·16354	·67464	·26114
740	4·39350	2·19653	1·19564	·69325	·26834
750	4·51305	2·25630	1·22817	·71211	·27564
760	4·63420	2·31687	1·26114	·73122	·28304
770	4·75696	2·37824	1·29454	·75060	·29054
780	4·88131	2·44041	1·32839	·77022	·29813
790	5·00728	2·50339	1·36267	·79009	·30583
800	5·13485	2·56717	1·39738	·81022	·31362
810	5·26402	2·63175	1·43253	·83060	·32151
820	5·39480	2·69713	1·46812	·85124	·32950
830	5·52718	2·76332	1·50415	·87213	·33758
840	5·66117	2·83030	1·54061	·89327	·34577
850	5·79676	2·89809	1·57751	·91466	·35405
860	5·93396	2·96668	1·61485	·93631	·36243
870	6·07276	3·03608	1·65262	·95821	·37090
880	6·21317	3·10627	1·69083	·98037	·37948
890	6·35518	3·17727	1·72948	1·00277	·38815

SLIGHTLY TUBERCULATED—(*concluded*).

Gallons per minute.	Diameter of pipe in inches.				
	7	8	9	10	12
	Value of *m*.				
	·00752	·00733	·00719	·00706	·00680
	Head of water in feet.				
900	6·49879	3·24907	1·76856	1·02544	·39692
910	6 64401	3·32167	1·80808	1·04835	·40579
920	6·79084	3·39508	1·84804	1·07152	·41476
930	6·93927	3·46929	1·88843	1·09494	·42383
940	7·08930	3·54430	1·92926	1·11861	·43299
950	7·24094	3·62011	1·97053	1·14254	·44225
960	7·39418	3·69672	2·01223	1·16672	·45161
970	7·54903	3·77414	2·05437	1·19115	·46107
980	7·70548	3·85236	2·09695	1·21584	·47062
990	7·86354	3·93138	2·13996	1·24078	·48028
1000	8·02320	4·01120	2·18341	1·26597	·49003

Strains on Tie-rods, &c., in Arched Roofs.

Arch.		Inclination of Tangent with Horizon.	Strains on Tie-rods in Lbs.			Length of arc, in feet.
Span, feet.	Rise, feet.		Rods, 1 foot apart.	Rods, 2 feet apart.	Rods, 3 feet apart.	
7½	1½	37° 34′	588	1,176	1,763	9·04
8	1½	36° 1′	649	1,298	1,949	9·45
9	1½	33° 13′	786	1,572	2,359	10·29
10	2	37° 33′	768	1,535	2,303	11·8
12	2½	38° 32′	868	1,735	2,603	13·81
12	3	42° 47′	801	1,601	2,402	14·84
14	3	39° 12′	1,006	2,012	3,018	16·42
16	4	42° 48′	1,052	2,103	3,155	19·47
18	4½	42° 48′	1,177	2,353	3,530	21·79
20	4½	40° 21′	1,379	2,759	4,138	23·44
24	5	38° 32′	1,725	3,450	5,175	27·47
24	6	42° 48′	1,552	3,104	4,656	28·74
30	6	37° 34′	2,202	4,404	6,606	33 86
30	7	41° 12′	2,014	4,028	6,042	35·26

Arched Roofs.—These roofs have been calculated with circumscribing arc outside 6 inches of brickwork. The line of thrust is tangential to the parabola, of which the vertex coincides with the upper 60° of the arc. 60° is too flat, but is usually adopted to save calculations.

SLIGHTLY TUBERCULATED—(*continued*).

Gallons per minute.	Diameter of pipe in inches.				
	7	8	9	10	12
	Value of m.				
	·00752	·00733	·00719	·00706	·00680
	Head of water in feet.				
460	1·69771	·84877	·46201	·26788	·10369
470	1·77232	·88607	·48232	·27965	·10825
480	1·84855	·92418	·50306	·29168	·11290
490	1·92637	·96309	·52424	·30396	·11766
500	2·00580	1·00280	·54585	·31649	·12251
510	2·08683	1·04331	·56790	·32928	·12746
520	2·16947	1·08463	·59039	·34232	·13250
530	2 25372	1·12675	·61332	·35561	·13765
540	2·33956	1·16967	·63668	·36916	·14289
550	2·42702	1·21339	66048	·38296	·14823
560	2·51608	1·25791	·68472	·39701	·15367
570	2·60674	1·30324	·70939	·41131	·15921
580	2·69900	1 34937	·73450	·42587	·16485
590	2·79288	1·39630	·76005	·44068	·17058
600	2·88835	1·44403	·78603	·45575	·17641
610	2·98543	1·49257	·81245	·47107	·18234
620	3·08412	1·54191	·83930	·48664	·18837
630	3·18441	1·59205	·86660	·50246	·19449
640	3·28630	1·64299	·89432	·51854	·20072
650	3·38980	1·69473	·92249	·53487	·20704
660	3·49491	1·74728	·95109	·55146	·21346
670	3·60161	1·80063	·98013	·56829	·21998
680	3·70993	1·85478	1·00961	·58538	·22659
690	3·81985	1·90973	1·03952	·60273	·23330
700	3·93137	1·96549	1·06987	·62033	·24011
710	4·04450	2·02205	1·10066	·63818	·24702
720	4·15923	2·07941	1·13188	·65628	·25403
730	4·27556	2·13757	1·16354	·67464	·26114
740	4·39350	2·19653	1·19564	·69325	·26834
750	4·51305	2·25630	1·22817	·71211	·27564
760	4·63420	2·31687	1·26114	·73122	·28304
770	4·75696	2·37824	1·29454	·75060	·29054
780	4·88131	2·44041	1·32839	·77022	·29813
790	5·00728	2·50339	1·36267	·79009	·30583
800	5·13485	2·56717	1·39738	·81022	·31362
810	5·26402	2·63175	1·43253	·83060	·32151
820	5 39480	2 69713	1·46812	·85124	·32950
830	5·52718	2·76332	1·50415	·87213	·33758
840	5·66117	2·83030	1·54061	·89327	·34577
850	5·79676	2·89809	1·57751	·91466	·35405
860	5·93396	2 96668	1·61485	·93631	·36243
870	6·07276	3·03608	1·65262	·95821	·37090
880	6·21317	3·10627	1·69083	·98037	·37948
890	6·35518	3·17727	1·72948	1·00277	·38815

Then total load on two planks

$= 2 \times \frac{3}{8} \times 112$ (Table I.)

$+ 2 \times \frac{3}{8} \times \frac{1}{4} \times 52$ (Table III.)

$= 77 + 9{\cdot}75 = 86{\cdot}75$

and $W = \frac{86{\cdot}75}{2} = 43{\cdot}375$.

log 2	$= 0{\cdot}30103$
2 log 2	$= 0{\cdot}60206$
log 43	$= 1{\cdot}63346$
add	$2{\cdot}23552$
log 175	$= 2{\cdot}24303$
log bd^3 = log 1·00	$= \bar{1}{\cdot}99249$

In Deflection—From Formula III.—

For teak $bd^3 = \frac{WL^2}{175}$.

Here $b = 4{\cdot}5$, $L = 2$, $W = 43$,

$$bd^3 = \frac{43 \times 2^2}{175} = 1{\cdot}0.$$

From Table, page 104, it is evident planks are amply strong enough.

Joists.

$W = 6 \times 2 \times 112 + 6 \times 2 \times \frac{1}{4} \times 52$

$+ 6 \times$ (say) $\frac{3\frac{1}{2} \times 5}{144} \times 62$, (Table III.)

$= 1344 + 156 + 45{\cdot}2 = 1445{\cdot}2$ lbs.

$L = 6$ feet.

log 1445·2	$= 3{\cdot}15987$
log 36	$= 1{\cdot}55630$
	$4{\cdot}71617$
log 200	$= 2{\cdot}30103$
log bd^3 = log 262	$= 2{\cdot}41514$

In Deflection—From Formula III.—

For sál $bd^3 = \frac{WL^2}{200} = \frac{1445{\cdot}2 \times 6^2}{200} = 262$.

See Table, page 104, and $b = 2''$, $d = 5''$ will do.

log 1445·2	$= 3{\cdot}15987$
log 6	$= {\cdot}77815$
	$3{\cdot}93802$
log 180	$= 2{\cdot}25527$
log bd^2 = log 48·1	$= 1{\cdot}68275$

In Transverse Strain—From Formula III.—

For sál $bd^2 = \frac{WL}{180} = \frac{1445{\cdot}2 \times 6}{180} = 48{\cdot}1$.

See Table, page 106, $b = 2''$, $d = 5''$ will do.

Make joists therefore $2'' \times 5''$.*

Note.—*It is generally sufficient to calculate joists, having a breadth of 2 inches for transverse strain only.*

Girder.

It will generally be cheaper to use a rolled iron beam than to build up a girder.

* It can be proved that when the same timoer is used for boards and joists a floor is most economically designed for deflection when the amount of timber in the planking is one-half that in the joists. The same remark applies to a planked roof on common rafters.

log 288	= 2·45939
log 9	= 0·95424
log denominator	= 3·41363
log 8	= 0·90309
log 8960	= 3·95230
log 921·1	= 2·96425
log numerator	= 7·81964
log denominator	= 3·41363
log W = log 25490	= 4·40[illegible]

Then Formula VII.—

$$W = \frac{8 \times c \times I}{l \times (d - r)}$$

Here $c = 8{,}960$ lbs. (Table IV.)

$l = 24 \times 12 = 288$ inches.

$d - r = \frac{18}{2} = 9$ (Table VII.)

Then $W = \frac{8 \times 8960 \times 921{\cdot}1}{288 \times 9}$

$= 25{,}490$ lbs.

Load is about the same as before, *i.e.*, 19,440 lbs., or girder as designed above is too strong. Another section must therefore be tried. If the angle-irons are made $2\frac{1}{2}'' \times 2\frac{1}{2}'' \times \frac{5}{16}''$ and the covering plates $5'' \times \frac{1}{2}''$, and the calculations worked out again as above, it will be found that a girder of this section is sufficiently strong.

When the cover or web plates are in more than one piece, it will be necessary to calculate the cover pieces and rivets at the joints. This can generally, however, be left to the manufacturers; but if any one wishes to design them himself, he is referred to the Chapter on Built-up Girders, in "*Wray on Construction.*"

L = 24

W =

=

=

See T

log 18000	$= 4{\cdot}25527$	K :
log 24	$= 1{\cdot}38021$	
	$= 5{\cdot}63548$	:
log 2240	$= 3{\cdot}35024$	The g
log K = log 192	$= 2{\cdot}28524$	foo
log 19440	$= 4{\cdot}28780$	Then
log 24	$= 1{\cdot}38021$	
	$= 5{\cdot}66801$	
log 2240	$= 3{\cdot}35024$	
log K = log 208	$= 2{\cdot}31777$	

log 18

log 5·25
log 30600
log 16·25

log 4·25
log 1825
log 12

log [illegible]
log [illegible]

of 6 feet in length of such a joist

$= 6 \times 12 \times (3\frac{1}{2} + 3) \times \frac{1}{2} \times \cdot 28$ (Table III.)

$= 65$ lbs.

Then K becomes $= 5190 + 5\cdot 41 \times 65$

$= 5190 + 355 = 5565.$

A further inspection of the Table shows that this section will do.

Make joists therefore $8'' \times 8'' \times \frac{1}{2}''$.

Girders.

Live load $= 24 \times 6 \times 112$

$= 16{,}128$ lbs.

Weight of flagging $= 24 \times 6 \times \frac{1}{6} \times 156$

$= 2{,}808$ lbs.

" " bricks $= 23 \times 189\cdot 4$ (from above)

$= 4{,}356$ lbs.

" " T-irons $= 22 \times 65$ (from above)

$= 1{,}430$ lbs.

Then total load exclusive of weight of iron in girder

$= 16128 + 2808 + 4356 + 1430$

$= 24{,}722$ lbs.

Then Table, page 116.

$K = W \times L$,

$W = \frac{24722}{2240}$ (for trial),

log 24722	$= 4\cdot 39269$	and $L = 24$ feet,
log 24	$= 1\cdot 38021$ $5\cdot 77290$	$\therefore K = \frac{24722 \times 24}{2240} = 266.$
log 2240	$= 3\cdot 35024$	From the Table it would appear that a
log 266	$= 2\cdot 42266$	rolled iron beam weighing 62 lbs. per foot run is suitable.
		Weight of such a beam
log 1488	$= 3\cdot 17318$	$= 62 \times 24 = 1{,}488$ lbs.,
log 24	$= 1\cdot 38021$ $4\cdot 55339$	and correct value of K $= 266 + \frac{1488 \times 24}{2240} = 266 + 15\cdot 9$
log 2240	$= 3\cdot 35024$	
log 15·9	$= 1\cdot 20315$	$= 281\cdot 9.$

Thus a girder of this section is too strong. A smaller section must therefore be tried. If the cover plates are made $7' \times \frac{5}{8}'$, and the calculations worked out again as above, it will be found that a girder of this section is sufficiently strong.

The remark at the end of Example I. applies equally in this case.

A further inspection of the Table shows that a larger section must be used.

Make therefore 18″ × 7″ *weighing* 75 *lbs. per foot run.*

If a built-up girder is to be used, then the following calculations must be made. Assume the girder to be of the form shown in Section IV., Table VII.

$$\text{Depth of girder} = \frac{1}{16} \times 24 \text{ feet}$$
$$= 18 \text{ inches.}$$

Assume angle-irons to be 3″ × 3″ × $\frac{3}{8}$″, and cover plates 9″ × $\frac{3}{8}$″, the web being $\frac{1}{4}$-inch thick.

Then from Table VII.—

$$I = \frac{bd^3 - (b_1 d_1{}^3 + b_2 d_2{}^3 + b_3 d_3{}^3)}{12}$$

$$= \frac{9 \times 18^3 - (2\tfrac{3}{4} \times 17\tfrac{1}{4}{}^3 + 5\tfrac{1}{4} \times 16\tfrac{1}{2}{}^3 + \tfrac{3}{4} \times 11\tfrac{1}{4}{}^3)}{12}$$

$$= \frac{52490 - (14230 + 23590 + 1068)}{12}$$

$$= \frac{52490 - 38888}{12}$$

$$= \frac{13602}{12} = 1133{\cdot}5.$$

Then Formula VII.—

$$W = \frac{8 \times c \times I}{l \times (d - v)}$$

Here c = 8,960 lbs. (Table IV.),

$l = 24 \times 12 = 288$ inches,

$d - v = \frac{18}{2} = 9$ (Table VII.)

$$\text{Then } W = \frac{8 \times 8960 \times 1133{\cdot}5}{288 \times 9}$$

= 31,350 lbs.

= safe load which this girder will support.

The actual load will be much the same as before, *i.e.*,

= 24722 + 1488 = 26,210 lbs.

log 18	= 1·25527
	3
	= 3·76581
log 9	= 0·95424
log 52490	= 4·72005
log 17·25	= 1·23802
	3
	3·71406
log 2·75	= 0·43933
log 14230	= 4·15339
log 16·5	= 1·21748
	3
	3·65244
log 5·25	= 0·72015
log 23590	= 4·37259
log 11·25	= 1·05100
	3
	3·15300
log 0·75	= $\bar{1}$·87506
log 1068	= 3·02806
log 288	= 2·45939
log 9	= 0·95424
log denominator	= 3·41363
log 8	= 0·90309
log 8960	= 3·95230
log 1133·5	= 3·05420
log numerator	= 7·90959
log denominator	= 3·41363
log 31350	= 4·49596

Make battens therefore $1\frac{1}{4}'' \times 1\frac{1}{2}''$.

N.B.—*In almost all cases, it will be sufficient to calculate battens by the deflection formula only.*

Common Rafters.

$W = 7{\cdot}118 \times 2{\cdot}25 \times 65 = 1{,}050$ lbs.

(The weight of the framing or roof timbers may always be safely omitted, it makes no *practical* difference, and the calculation is troublesome).

log 7·118	= 0·85240
	2
	1·70480
log 1050	= 3·02118
	4·72598
log 200	= 2·30103
log 266	= 2·42495
log 7·118	= 0·85240
log 1050	= 3·02118
	3·87358
log 180	= 2·25527
log 41·5	= 1·61831

Deflection—Formula III.—

For sál $bd^3 = \dfrac{WL^2}{200} = \dfrac{1050 \times 7{\cdot}118^2}{200}$

$= 266.$

From Table, page 104, it is seen that $b = 3''$, $d = 4\frac{1}{2}''$ will do.

Transverse Strain—Formula III.—

For sál $bd^2 = \dfrac{WL}{180} = \dfrac{1050 \times 7{\cdot}118}{180}$

$= 41{\cdot}5.$

From Table, page 106, it is seen that $b = 3''$; $d = 3\frac{3}{4}''$ will do, a less result than before.

Make common rafters $3'' \times 4\frac{1}{2}''$.

*N.B.—*In almost all cases it will be sufficient to calculate common rafters by the deflection formula only.*

Purlins.

$W = 6{\cdot}75 \times 7{\cdot}118 \times 65 = 3{,}060$ lbs.

(*see* remarks under common rafters).

log 6·75	= 0·82865
	2
	1·65730
log 3060	= 3·48572
	5·14302
log 200	= 2·30103
log 695	= 2·84199

Deflection—Formula III.—

For sál $bd^3 = \dfrac{WL^2}{200} = \dfrac{3060 \times 6{\cdot}75^2}{200}$

$= 695.$

From Table, page 104, it is seen that $b = 4\frac{3}{4}''$, $d = 5\frac{1}{4}''$ will do.

Transverse Strain—Formula III.—

* It can be proved theoretically that a roof is most economically designed when the amount of timber in the battens is one-third of that in the common rafters. If the proportion be in excess of this the rafters should be spaced closer together, if less further apart.

Roofs.

EXAMPLE III. KING-POST TRUSS. (*Plate* I.)

A roof is to be constructed with a King-post Truss, the clear span being 24 feet. The trusses to be $6\frac{3}{4}$ *feet apart, and the common rafters* $2\frac{1}{4}$ *feet apart, each from centre to centre. Timber, sál wood. Roof covering to be double Allahabad tiling, on battens 1 foot apart from centre to centre. Slope of roof 26° 35′, or 1 in 2. Walls 18 inches thick.*

Then Span of Truss $= 24 + 2\left(\frac{1}{2} \times 1\frac{1}{2}\right) = 25\frac{1}{2}$ *feet.*

(*See Plate* I., *Fig.* i.).

Construction of Diagram.

Make AB = $25\frac{1}{2}$ feet.

Bisect AB in D.

Erect perpendicular DC, making DC = $\frac{1}{4}$ AB.

Bisect AC and BC in E and F.

Join ED and FD.

Battens.

$$\left.\begin{array}{l}\text{Weight of double Allahabad til-}\\ \text{ing reduced to normal}\end{array}\right\} = 30 \text{ lbs. (Table III.)}$$

$$\left.\begin{array}{l}\text{Wind pressure normal to a roof}\\ \text{sloping } \frac{1}{2}\end{array}\right\} = 35 \text{ lbs. (page 98).*}$$

Total, $= \overline{65}$ lbs. per s. ft.

$W = 1 \times 2\frac{1}{4} \times 65 = 146$ lbs.

$L = 2{\cdot}25$ feet.

log 2·25	= 0·35218
	2
	0·70436
log 146	= 2·16435
	2·86871
log 200	= 2·30103
log 369	= 0·56768

Deflection—See Formula III.—

For sál $bd^3 = \frac{WL^2}{200} = \frac{146 \times 2{\cdot}25^2}{200}$

$= 3{\cdot}69.$

From Table, page 104, it is seen that $b = 1\frac{1}{4}''$, $d = 1\frac{1}{2}''$ will do.

log 2·25	= 0·35218
log 146	= 2·16435
	2·51653
log 180	= 2·25527
log 1·82	= 0·26126

Transverse Strain—See Formula III.—

For sál $bd^3 = \frac{WL}{180} = \frac{146 \times 2{\cdot}25}{180} = 1{\cdot}82.$

From Table, page 106, it is seen that $b = 1\frac{1}{4}''$, $d = 1\frac{1}{4}''$ will do, a less result than before.

* If considered desirable the wind pressure may as explained on page 99 be reduced to 30 lbs. in this case.

Formula V.—When length is between 12 and 24 times least sectional dimension,

$$S = \frac{2P}{c}$$

For sál, $c = 1210$ (Table IV.)

Then $S = \frac{2 \times 12100}{1210} = 20$ sq. inches.

Make principal rafters 4" × 5".

Strap and Bolt at foot of principal Rafter.

See Table, page 112, and *make strap $1\frac{1}{2}" \times \frac{3}{8}"$ and bolt $1\frac{1}{2}"$ diameter.*

Round Iron Tie-Rod (if used instead of a wooden tie-beam).

Formula VIII(b)—

$$P = \frac{13}{16} W \cot \theta \text{ (neglecting } w\text{)}.$$

$$= \frac{13}{16} W \cot 26° 33' = 1{\cdot}62\ W.$$

$$= 1{\cdot}62 \times 6700 \text{ (see above)}.$$

$$= 10{,}810 \text{ lbs.}$$

And $P = S \times t$ (Formula IV.)

For wrought-iron $t = 11200$ (Table IV.),

and $S = \pi r^2$.

$$\therefore \text{diameter} = 2r = \sqrt{\frac{10810 \times 4}{3{\cdot}1416 \times 11200}}$$

$$= 1{\cdot}11.$$

log 10810	= 4·03342
log 4	= 0·60206
log numerator	= 4·63548
log 3·1416	= 0·49715
log 11200	= 4·04921
log denominator	= 4·54636
Subtract	2)0·08912
log 1·11	= 0·04456

Make tie-rod $1\frac{1}{8}"$ diameter.

Abstract of Scantlings.

Battens,	... ...	$1\frac{1}{4}" \times 1\frac{1}{2}"$
Common rafters,	...	$3" \times 4\frac{1}{2}"$
Purlins,	... ...	$4\frac{3}{4}" \times 5\frac{1}{4}"$
Principal rafters,	...	$4" \times 5"$
Tie-beams,	... ...	$4" \times 5"$
Struts,	... ...	$4" \times 4"$
Straps at foot of principal rafter,	... ...	$1\frac{1}{2}" \times \frac{3}{8}"$
Bolts do. do.,	...	$1\frac{1}{2}"$ diam.
Straps at head and foot of king-post,	...	$1\frac{1}{2}" \times \frac{3}{8}"$
Bolts do. do.,	...	$1"$ diam.
King-post (double),	...	$5" \times 2"$

For sál $bd^2 = \frac{WL}{180} = \frac{3060 \times 6{\cdot}75}{180}$

$= 114{\cdot}8.$

log 6·75	$=0{\cdot}82865$
log 3060	$=3{\cdot}48572$
	$4{\cdot}31437$
log 180	$=2{\cdot}25527$
log 114·8	$=2{\cdot}05910$

From Table, page 106, it is seen that $b = 4\frac{1}{4}''$, $d = 5\frac{1}{4}''$ will do, a smaller result than before.

Make purlins $4\frac{3}{4}'' \times 5\frac{1}{4}''$.

N.B.—*In almost all cases it will be sufficient to calculate purlins by the deflection formula only.*

See Table, page 108, for a clear internal span of 24 feet, trusses 6·75 feet apart. Principal rafter should be $4'' \times 5''$.

When the Table does not apply, the following calculations must be made:—

Weight of double Allahabad tiling	= 34 lbs. (Table III.)
Wind pressure take as if normal	= 35 lbs. (page 98).
Total,	= 69 lbs.

Then Formula VIII(a)—

$$P = \left(\frac{13}{16} W + \frac{w}{2}\right) \operatorname{cosec} \theta.$$

Now as W is partly made up of wind pressure, this formula gives a result slightly in excess of the truth, and thus, except when a ceiling is attached to the tie-beam, w may always be [illegible] ly neglected.

The above formula [illegible] stance becomes

$P = \frac{13}{16}$ W [illegible]

W = 1·82 [illegible]

(The weight of the [illegible] of Allahabad [illegible] lected).

Then P = 1·82 [illegible]

1·82	$=0{\cdot}26007$
6700	$=3{\cdot}82607$
12190	$=4{\cdot}08614$

Formula IX (a)—

$$P = \left(\frac{5}{6} W + \frac{w}{2}\right) \operatorname{cosec} \theta.$$

This formula with a normal wind pressure included in W gives a result somewhat larger than the true one; as there is no ceiling on tie-beam w may be neglected, so may weight of framing.

log 1·88	= 0.27415	Then $W = 69 \times 18{\cdot}3 \times 6{\cdot}75$
log 8600	= 3·93449	$= 8{,}600$ lbs.,
log 16150	= 4·20864	and $P = \frac{5}{6} \times 8600 \times \operatorname{cosec} 26° 35'$

$$= 1{\cdot}88 \times 8600$$
$$= 16{,}150 \text{ lbs.}$$

The principal rafters are supported laterally by battens at 1 foot central intervals, so that length is between 1 and 8 times least sectional dimension, and Formula V.,

$$P = S \times c.$$

For sál $c = 1210$ (Table IV.)

Then $S = bd = \frac{16150}{1210} = 13{\cdot}3$.........(i).

Transverse Strain—Formula III.—

For sál $bd^2 = \frac{WL}{180}$.

$W = 6{\cdot}1 \times 6{\cdot}75 \times 65 = 2{,}680$ lbs.

$L = 6{\cdot}1$

log 2680	= 3·42813	$bd^2 = \frac{2680 \times 6{\cdot}1}{180} = 90{\cdot}8$, ...(ii).
log 6·1	= 0.78532	
	4·21345	
log 180	= 2·25527	Now
log 90·8	= 1·95818	

$b = 2{\cdot}13''$, $d = 6\frac{1}{4}''$ satisfies equation (i).

$b = 2{\cdot}31''$, $d = 6\frac{1}{4}''$ " " (ii).

(Table, page 106).

Add the two values of b, *and make principal rafters* $4\frac{1}{2}'' \times 6\frac{1}{4}''$.

N.B.—*For the theory involved in the above method, see "Roorkee Manual of Applied Mechanics," Vol. I., pages* 281-287.

EXAMPLE V. (*Plate* II.)

AN IRON TRUSS OVER A CLEAR SPAN OF FROM 12 TO 26 FEET.

A roof is to be constructed over a Barrack with a clear internal span of 24 feet; the truss to be of the form shown in the diagram, and the shape to be as described in the "Construction of Diagram" below. The trusses to be at $6\frac{3}{4}$ feet intervals, and the purlins, common rafters, and battens to be of sál wood: the common rafters being $2\frac{1}{4}$ feet apart from centre to centre. The principal rafters to be of T*-iron, the struts of angle-iron, and all the tie-rods of round bar-iron. The roof covering to be of double Allahabad tiling, and the slope of the roof to be* 26° 35′, *or* 1 *in* 2. *Walls* 18 *inches thick.*

From the above it will be seen that the roof will, in all respects, except the truss, be the same as that given in Example III.

As in Example III.—

Make the battens, ... $1\frac{1}{4}'' \times 1\frac{1}{2}''$.
,, ,, common rafters, ... $3'' \times 4\frac{1}{2}''$.
,, ,, purlins, ... $4'' \times 5''$.

Also, as in Example III., the span of the truss will be $25\frac{1}{2}$ feet.

(*See Plate* II.)

Construction of Diagram. Make AB $= 25\frac{1}{2}$ feet.

Bisect AB in C.

Erect perpendicular CD $= \frac{1}{4}$ AB.

Join AD and BD, and bisect them in E and F.

Draw EG and FH perpendicular to AD and BD.

Make EG and FH each $= \frac{1}{10}$ AB (or nearly so) [= (say) $2\frac{1}{2}$ feet].

Join AG, GD, BH, HD, and GH.

Then—

AD and BD are *principal rafters.*

EG and FH are *struts.*

AG, GD, BH, HD, and GH are *tie-rods.*

Let W = the entire weight of the half truss with its load.

It will be sufficiently accurate for the purposes of this calculation to assume

Strap and bolt at foot of principal rafter.

log 1·66	= 0·22010
log 8600	= 3·93449
log 14260	= 4·15459

Formula IX. (b) neglecting w,

Tension on tie-beam $= \frac{5}{6}$ W cot θ,

$= \frac{5}{6} \times 8600 \times \cot 26° 35'$,

$= 1·66 \times 8600 = 14,260$ lbs.

Formula XI. Section of heel strap

$= \frac{P}{2t} = \frac{14260}{2 \times 11200}$ (Table IV.)

Then S = 0·631 square inch.

Make strap $1\frac{3}{4}'' \times \frac{3}{8}''$.

From Formula XII.—

Diameter of bolt $= \dfrac{\text{tension on tie-beam}}{b \times \frac{5}{3} c}$.

Here tension on tie-beam = 14,260 lbs.

b = breadth of principal rafter,

= 4·5 inches.

c = 1210, sál (Table IV.)

Diameter of bolt $= \dfrac{14260}{4·5 \times 2000} = \dfrac{14260}{9000}$

= 1·58 inches.

Make bolt $1\frac{5}{8}''$ *diameter.*

Abstract of Scantlings.

Battens, ...	... ...	$2\frac{1}{2}'' \times 3\frac{1}{2}''$
Principal rafters, ...	...	$4\frac{1}{2}'' \times 6\frac{1}{4}''$
Tie-beam, ...	... ...	$4\frac{1}{2}'' \times 6\frac{1}{4}''$
Struts, ...	... ...	$4\frac{1}{2}'' \times 4\frac{1}{2}''$
Queen-posts,	... ...	$6\frac{1}{4}'' \times 2\frac{1}{4}''$ (double).
Straining beam, ...	...	$4\frac{1}{2}'' \times 6\frac{1}{4}''$
Straining sill,	... ...	$2'' \times 4\frac{1}{2}''$
Straps at heel of principal rafters,	... ...	$1\frac{3}{4}'' \times \frac{3}{8}''$
Bolts do., do.,	...	$1\frac{5}{8}''$ diam.
Bolts elsewhere, ...	...	$1\frac{1}{8}''$,,
Straps at feet of Queen-posts,		$1\frac{3}{4}'' \times \frac{1}{4}''$

The diagram is now complete. The length of each line in the diagram measured off on the scale will give the amount of stress on the part of the truss which it represents.

By measuring off these lines, it is found that the amount of stress in

$A_1 = 15{,}250$ lbs. compression.
$A_2 = 13{,}650$,, ,,
$A_3 = 3{,}000$,, ,,
$C_1 = 13{,}800$,, tension.
$C_2 = 6{,}160$,, ,,
$C_3 = 7{,}950$,, ,,

Principal Rafter.

Assume $h = 3{\cdot}04$. Then Table II., page 120, $R = \frac{\text{length}}{3{\cdot}04}$.

Here length of principal rafter $= 7{\cdot}118 \times 12 = 86$ inches; and greatest compression $= A_1 = 15{,}250$ lbs.

Then $R = \frac{86}{3{\cdot}04} = 28$.

With this value of R,

$c_1 = 7103$, and $S = \frac{15250}{7103} = 2{\cdot}18$.

From Table I. it is seen that a **T**-iron $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$ has the required area of section with the value of h assumed above.

Make principal rafters $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$.

Strut.

Assume $h = 1{\cdot}06$.

Length of strut $= 2{\cdot}5 \times 12 = 30$ inches.

Compression on strut $= 3{,}000$ lbs.

Then $R' = \frac{30}{1{\cdot}06} = 28{\cdot}5$. With this value of R', $c_1 = 4300$ nearly; and $S = \frac{3000}{4300} = {\cdot}700$. From Table I. it is seen that an **L**-iron $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times 1\frac{1}{4}''$

that W is equally distributed along the principal rafter, and therefore that $\frac{W}{4}$ is borne at D, $\frac{W}{2}$ at E, and $\frac{W}{4}$ at A. Also as W is partly made up of wind pressure, taken as acting with its normal component vertically, this will give a result somewhat in excess of the true one, and thus in estimating W, the weight of the framing and timbering may be safely neglected, a great saving in trouble.

From Example III., W = 6,700 lbs.

Diagram of Forces.

Construct a diagram of forces as follows (*see Fig.* 2, *Plate* II.) :—

Draw a line parallel to R (*Fig.* 1), and on it, on any convenient scale, in this case 4,000 lbs. = 1 inch, set off W = 6,700 lbs.

First take the forces at A. From one end of R, set off $\frac{W}{4}$ = 1,675 lbs. From the end of this draw A_1 parallel to AE, and from the other end of R draw C_1 parallel to AG. Produce A_1 and C_1 until they meet.

Secondly, take forces at E. From the point where A_1 meets R, set off along R a length $\frac{W}{2}$ = 3,350 lbs.; from this point, and from the other extremity of A_1, draw A_2 and A_3 respectively parallel to ED and GE. Produce them until they meet.

Thirdly, take forces at G. From the upper extremities of R and A_3, draw C_3 and C_2 parallel to GH and DG, respectively; produce them until they meet.

has the required area of section, w[...]
the value of h assumed above.
Make struts $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{4}''$.

Tension on tie-rod $C_1 = 13{,}800$ lbs.
Formula IV.,—$P = S \times t$.
Here $t = 11200$ (Table IV.),
and $2r = \sqrt{\dfrac{4 \times 13800}{3{\cdot}1416 \times 11200}} = 1{\cdot}25$.
Make rod $1\frac{1}{4}''$ *diameter.*

Tie-rod AG or C_1.

log 4	$= 0{\cdot}60206$
log 13800	$= 4{\cdot}13987$
	$4{\cdot}74193$
log 11200	$= 4{\cdot}04921$
log 3·1416	$= 0{\cdot}49715$
Subtract	$4{\cdot}54636$
	$2)0{\cdot}19557$
log 1·25	$= 0{\cdot}09778$

Tension on tie-rod $C_2 = 6{,}100$ lbs.
As before $2r = \sqrt{\dfrac{4 \times 6100}{3{\cdot}1416 \times 11200}}$
$= {\cdot}832$.
Make rod $\frac{7}{8}''$ *diameter.*

Tie-rod GD or C_2.

log 4	$= 0{\cdot}60206$
log 6100	$= 3{\cdot}78532$
	$4{\cdot}38738$
log denominator	$= 4{\cdot}54636$
	$2)\bar{1}{\cdot}84102$
log ·832	$= \bar{1}{\cdot}92051$

Tension on tie-rod $C_3 = 7{,}950$ lbs.
As before $2r = \sqrt{\dfrac{4 \times 7950}{3{\cdot}1416 \times 11200}}$
$= {\cdot}950$.
Make tie-rod $1''$ *diameter.*

Tie-rod GH or C_3.

log 4	$= 0{\cdot}60206$
log 7950	$= 3{\cdot}90036$
	$4{\cdot}50242$
log denominator	$= 4{\cdot}54636$
	$2)\bar{1}{\cdot}95616$
log ·950	$= \bar{1}{\cdot}97808$

Abstract of Scantlings.

Battens, ...
Common rafters ...
Purlins, ...
Principal rafters ...
Struts ...

draw A_4 and A_2 respectively parallel to EJ and EF, and produce these lines till they meet.

Thirdly, take the forces at J:—

From extremity of A_4 draw C_4 parallel to FJ. The line between the point where C_4 cuts C_1 and extremity of $\frac{W}{6}$ represents C_2.

Fourthly, take the forces at F:—

From the junction of C_2 and C_4 draw A_5 parallel to KF, and from extremity of $\frac{W}{3}$ draw A_3 parallel to FD. Produce them till they meet.

Fifthly, take the forces at K:—

From the point of junction of A_3 A_5, and from the upper extremity of $\frac{W}{6}$, draw C_5 and C_3 respectively parallel to DK and KM, and produce them until they meet.

The diagram of stresses is now complete. The length of each line on the diagram measured off on the scale will give the amount of stress on the part of the truss, which it represents.

By measuring off these lines, it is found that the amount of stress in

$A_1 =$	20,800	lbs.	compression.
$A_2 =$	19,500	,,	,,
$A_3 =$	15,000	,,	,,
$A_4 =$	2,550	,,	,,
$A_5 =$	3,850	,,	,,
$C_1 =$	18,800	,,	tension.
$C_2 =$	15,200	,,	,,
$C_3 =$	10,900	,,	,,
$C_4 =$	3,600	,,	,,
$C_5 =$	5,800	,,	,,

Common Rafters.

log 6·1	= 0·78532
	2
	1·57064
log 880	= 2·94448
	4·51512
log 200	= 2·30103
log 163·8	= 2·21409

$W = 65 \times 2\frac{1}{4} \times 6{\cdot}1 = 880$ lbs.

Deflection—Formula III.—

For sál $bd^3 = \frac{WL^2}{200}$

$= \frac{880 \times 6{\cdot}1^2}{200} = 163{\cdot}8.$

See Table, page 104, and

Make common rafters $2\frac{3}{4}'' \times 4''$.

Purlins.

log 6·75	= 0·82930
	2
	1·65860
log 2690	= 3·42975
	5·08835
log 200	= 2·30103
log 613	= 2·78732

$W = 65 \times 6{\cdot}1 \times 6{\cdot}75 = 2{,}690$ lbs.

Deflection—Formula III.—

For sál $bd^3 = \frac{WL^2}{200}$

$= \frac{2690 \times 6{\cdot}75^2}{200} = 613.$

See Table, page 104, and

Make purlins $4\frac{1}{4}'' \times 5\frac{1}{4}''$.

The remarks made in Example V. regarding W apply equally in this case; $\frac{W}{6}$ is borne at A, $\frac{W}{3}$ at E and F, and $\frac{W}{6}$ at D.

The value of W is the same as in Example IV., *i.e.*, 8,600 lbs.

Diagram of Forces.

Construct a diagram of forces as shown in *Fig.* 2, *Plate* III., as follows:—
Set off R = W = 8,600 lbs., on a line parallel to R on a scale of 5,000 feet to the inch. Divide this line into four parts $\frac{W}{6}, \frac{W}{3}, \frac{W}{3}, \frac{W}{6}$.

First, take forces at A, *Fig.* 1:—

From upper extremity of $\frac{W}{6}$ draw A_1 parallel to AE, and from upper extremity of R draw C_1 parallel to AJ, and produce these lines until they meet.

Secondly, take forces at E, *Fig.* 1:—

From the extremities of A_1 and $\frac{W}{3}$

page 120, and as the strut is partially fixed,

Make strut A_5 $2'' \times 2'' \times \frac{1}{4}''$.

Tie-rod C_1.

log 4	= 0·60206
log 18800	= 4·27415
	4·87621
log 3·1416	= 0·49715
log 14000	= 4·14612
	4·64327
Subtract	2)0·23294
log 1·32	= 0·11647

From Formula IV., $P = S \times t$.

Here $P = 18{,}800$,

$t = 14{,}000$ (Table III.)

Then $S = \frac{18800}{14000} = \pi r^2$.

Therefore $2r = \sqrt{\frac{4 \times 18800}{3{\cdot}1416 \times 14000}}$

$= 1{\cdot}32$.

Make tie-rod $1\frac{3}{8}''$ *diameter.*

Tie-rod C_2.

log 4	= 0·60206
log 15200	= 4·18184
	4·78390
log denominator	= 4·64327
	2)0·14063
log 1·18	= 0·07031

As before $2r = \sqrt{\frac{4 \times 15200}{3{\cdot}1416 \times 14000}}$

$= 1{\cdot}18$.

Make tie-rod $1\frac{1}{4}''$ diameter.

Tie-rod C_3.

log 4	= 0·60206
log 10900	= 4·03742
	4·63948
log denominator	= 4·64327
	2)$\bar{1}$·99621
log 1·00	= $\bar{1}$·99810

As before $2r = \sqrt{\frac{4 \times 10900}{3{\cdot}1416 \times 14000}}$

$= 1{\cdot}00$.

Make tie-rod $1''$ *diameter.*

Tie-rod C_4.

log 4	= 0·60206
log 3600	= 3·55630
	4·15836
log denominator	= 4·64327
	2)$\bar{1}$·50509
log ·58	= $\bar{1}$·75254

As before $2r = \sqrt{\frac{4 \times 3600}{3{\cdot}1416 \times 14000}}$

$= {\cdot}58$.

Make tie-rod $\frac{5}{8}''$ *diameter.*

Tie-rod C_5.

log 4	= 0·60206
log 5800	= 3·76342
	4·36548
log denominator	= 4·64327
	2)$\bar{1}$·72221
log ·731	$\bar{1}$·86110

As before $2r = \sqrt{\frac{4 \times 5800}{3{\cdot}1416 \times 14000}}$

$= {\cdot}731$.

Make tie-rod $\frac{3}{4}''$ *diameter.*

<u>*Principal Rafter.*</u>

Assume $h = 3{\cdot}04$. Then Table II., page 120, $R = \frac{\text{length}}{3{\cdot}04}$.

Here length $= 6{\cdot}1 \times 12 = 73$ inches.

And greatest compression $A_1 = 20{,}800$ lbs.

Then $R = \frac{73}{3{\cdot}04} = 24$. With this value of R, $c_1 = 7{,}517 \times \frac{5}{4}$ lbs. $= 9{,}400$ lbs., and $S = \frac{20800}{9400} = 2{\cdot}20$.

From Table I. it is seen that a **T**-steel $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$ has the required area of section with the value of h assumed above.

Make principal rafters $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$.

<u>*Strut* A_4.</u>

Assume $h = 1{\cdot}06$.

Length of strut $= 2 \times 12 = 24$ inches.

Compression on $A_4 = 2{,}550$ lbs.

Then $R' = \frac{24}{1{\cdot}06} = 22{\cdot}6$. With this value of R' $c_1 = 5{,}255 \times \frac{5}{4}$, and $S = \frac{2550}{6550} = 0{\cdot}386$.

From Table I. it is seen that an **L**-steel $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{8}''$ has the required area of section with the value of h assumed above.

Make strut A_4 $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{8}''$.

<u>*Strut* A_5.</u>

Assume $h = 1{\cdot}41$.

Length of strut $= 4\frac{1}{2} \times 12 = 54$ inches.

Then $R' = \frac{54}{1{\cdot}41} = 38{\cdot}2$. With this value of R' $c_1 = 3{,}062 \times \frac{5}{4}$; and as compression of strut $A_5 = 3850$.

Then $S = \frac{3850}{3840} = 1{\cdot}00$. *See* Table I.,

Example VII. (*Plate* IV.)

Iron Truss for a Roof of over 60 feet span.

A roof with an Iron Truss of the form given in the diagram is to be constructed over an Artillery Gun-shed, with a clear internal span of 72 feet, the walls being 3 feet thick: a truss to be over each pier, and one over the centre of each arch, the intervals being therefore 6 feet from centre to centre. The principal rafters to be of **T***-iron, or of two angle-irons, back-to-back; the struts of angle-iron; and the tie-rods of round bar-iron. The battens, common rafters, and purlins, to be of sál wood, the battens being at 1 foot intervals, and the common rafters at 2 feet intervals, from centre to centre. The slope of the roof to be 26° 35′, or 1 in 2, and the roof covering to be single Allahabad tiling.*

The clear span of the truss will be $72 + 2\left(\frac{1}{2} \times 3\right) = 75$ *feet.*

(*See Plate* IV.)

Construction of Diagram of half-truss.

Make AB = $37\frac{1}{2}$ feet.

Erect perpendicular BC = $\frac{1}{2}$ AB.

Join AC, and divide it into four equal parts in D, E, F.

Drop perpendicular EH = $\frac{1}{11} \times 2$ AB (or nearly so) = (say $6\frac{2}{3}$ feet).

Join AH, HC, drop perpendiculars DG and FJ, and join GE, EJ.

Draw HL parallel to AB.

Then—

AC is the *principal rafter.*

DG, EH, and FJ are *struts,*

AG, GE, EJ, JC, GH, HJ and HL are *tie-rods.*

Battens.

Weight per square foot of single Allahabad tiling reduced to normal roof sloping $\frac{1}{2}$ (Table III.)	= 15 lbs.
Wind pressure normal on a light roof sloping $\frac{1}{2}$, see remarks, page 99,	= 18 „
Total	= 33 „

Abstract of Scantlings.

Make :—

Principal rafters, $3\frac{1}{2}'' \times 3\frac{1}{2}'' \times \frac{3}{8}''$ T-steel.
Strut EJ, ... $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{8}''$ L-
" FK, ... $2'' \times 2'' \times \frac{1}{4}''$ " "
Tie-rods AJ $= 1\frac{3}{8}''$ round steel.
" JK $= 1\frac{1}{4}''$ "
" KM $= 1''$ "
" JF $= \frac{5}{8}''$ "
" DK $= \frac{3}{4}''$ "

(3). Weight of half truss.

Then $W = 42 \times 6 \times 35\ (17 + 18)$
$+$ weight of half truss.

Now weight of truss $= 1\frac{3}{4}$ times weight of principal rafters (approximately).

Assume principal rafter $= 4'' \times 4'' \times \frac{1}{2}''$ in section.

Then weight of half truss $= 42 \times 12 \times (4 + 3\frac{1}{2}) \times \frac{1}{2} \times \cdot 28$ (Table III.),

and $W = 8820 + 529$
$= 9,349$ lbs.

The weight may be considered as uniformly distributed along the principal rafter, or that

$\frac{W}{8}$ is borne at A.

$\frac{W}{4}$ „ „ each of D, E, and F.

$\frac{W}{8}$ „ „ C.

<u>*Diagram of Forces.*</u>

Construct a diagram of forces as shown on *Fig.* 2, *Plate* IV., as follows :—

On any convenient scale, in this case 6,000 lbs. = one inch, draw a line R parallel to R, *Fig.* 1, and on it set off a distance = 9,349 lbs. Divide this into parts $\frac{W}{8}$ and $\frac{W}{4}$ as shown in *Fig.* 2.

1*st.* Take forces at A :—From upper extremities of R and $\frac{W}{8}$ draw C_1 and A_1 respectively parallel to AG and AD, and produce these lines till they meet.

2*nd.* Take forces at D.—From extremities of A_1 and $\frac{W}{4}$ draw A_5 and A_2 respectively parallel to GD and DE, and produce them until they meet.

Then $W = 1 \times 2 \times 33 = 66$.

Deflection—Formula III.—

For sál $bd^3 = \frac{WL^2}{200} = \frac{66 \times 2^2}{200} = 1{\cdot}32$.

See Table, page 104, and

Make battens 1″ × 1¼″.

Common Rafters.

log 10·5	= 1·02118
	2
	2·04236
log 691	= 2·83947
	4·88183
log 200	= 2·30103
log 381	= 2·58080

Length of rafter unsupported = 10½ feet.

Then $W = 33 \times 2 \times 10\frac{1}{2} = 691$ lbs.

Deflection—Formula III.—

$$\text{For sál } bd^3 = \frac{WL^2}{200} = \frac{691 \times 10{\cdot}5^2}{200} = 381.$$

See Table, page 104, and

Make common rafters 3″ × 5″.

Purlins.

log 6	= 0·77815
	2
	1·55630
log 2080	= 3·31806
	4·87436
log 200	= 2·30103
log 375	= 2·57333

Length of purlin = 6 feet.

Then $W = 33 \times 10\frac{1}{2} \times 6 = 2{,}080$ lbs.

Deflection—Formula III.—

$$\text{For sál is } bd^3 = \frac{WL^2}{200} = \frac{2080 \times 6^2}{200} = 375.$$

See Table, page 104, and

Make purlins 4¼″ × 4½″.

Truss.

In considering the weight on one side of the truss, it will not be desirable in this case to neglect the weight of the truss itself, as it is of considerable size. Then W may be taken to be made up as follows :—

(1). Single Allahabad Tiling, 17 lbs. per square foot (Table III.)

(2). Wind pressure normal to a light roof sloping ½ = 18 lbs. per square foot (*see* page 99) taken as acting vertically. This is in excess of truth, and consequently weight of common rafters and purlins may be neglected.

Measure off the length of each line on the scale, thus—

$A_1 = 26{,}300$ lbs. compression.
$A_2 = 25{,}400$,, ,,
$A_3 = 24{,}400$,, ,,
$A_4 = 23{,}500$,, ,,
$A_5 = A_7 = 2{,}160$,, ,,
$A_6 = 4{,}200$,, ,,
$C_1 = 23{,}800$,, tension.
$C_2 = 20{,}500$,, ,,
$C_3 = 11{,}400$,, ,,
$C_4 = 9{,}610$,, ,,
$C_5 = 13{,}400$,, ,,
$C_6 = C_7 = 3{,}400$,, ,,

Principal Rafter.

Greatest compression is that on $A_1 = 26{,}300$ lbs.

Table, page 120, assume $h = 3{\cdot}35$.

Then $R = \frac{10{\cdot}5 \times 12}{3{\cdot}35} = 37$. With this value of R, $c_1 = 6{,}256$ lbs.

Then $S = \frac{26300}{6256} = 4{\cdot}18$.

No section of T-iron given in table corresponds with these two values of h and S.

Try $4'' \times 4'' \times \frac{1}{2}''$, then $h = 3{\cdot}80$.

$R = \frac{10{\cdot}5 \times 12}{3{\cdot}80} = 33$, and $c_1 = 6{,}550$ lbs.

Then $S = \frac{26300}{6550} = 4{\cdot}0$ square inches.

A T-iron $4\frac{1}{2}'' \times 4\frac{1}{2}'' \times \frac{1}{2}''$ has a sectional area $= 4{\cdot}25$ square inches, which will do. Therefore

Make principal rafters $4\frac{1}{2}'' \times 4\frac{1}{2}'' \times \frac{1}{2}''$.

Struts $A_5 = A_7$.

Compression on each $= 2{,}160$ lbs.

Assume $h = 1{\cdot}06$. Then $R = \frac{3 \times 12}{1{\cdot}06} = 34$, and $c_1 = 6{,}467$ lbs.

Then $S = \frac{2160}{6467} = {\cdot}33$ square inch.

3rd. Take forces at G.—From junction of A_2 and A_5, draw C_6 parallel to EG, and produce it until it meets C_1. The portion of C_1 lying between this point and extremity of $\frac{W}{8}$ represents C_2.

4th. An inspection of the forces at F shows, that whatever be the amount of compression on EF and FC, the compression on FJ, A_7, is equal to that on DG, A_5; and further it follows from this that tension on EJ, C_7, is equal to tension on EG, C_6. Then take forces at E. From extremity of $\frac{W}{4}$ draw A_3 parallel to EF, and produce A_5 to meet it. From this point, and extremity of C_6 respectively, draw C_7 and A_6 parallel to JE and HE, and produce these lines till they meet.

5th. Take forces at H.—From junction of C_7 and A_6, and extremity of $\frac{W}{8}$ respectively, draw C_4 and C_3 parallel to JH and HL, and produce them until they meet.

6th. Take forces at F.—From extremities of $\frac{W}{4}$ and A_3 respectively, draw A_4 and A_7 parallel to FC and JF, and produce them until they meet.

7th. Take forces at J.—Produce C_4 till it meets A_4, C_4 thus produced represents C_5.

The diagram of forces is now complete.

Tie-rod C_5.

Here $P = 13,400$ lbs.,

and $2r = \sqrt{\dfrac{4 \times 13400}{3\cdot1416 \times 11200}}$

$= 1\cdot23.$

log 4	$= 0\cdot60206$
log 13400	$= 4\cdot12710$
	$4\cdot72916$
log denominator	$= 4\cdot54636$
	$2)\,0\cdot18280$
log 1·23	$= 0\cdot09140$

Make tie-rod C_5 $1\frac{1}{4}''$ diameter.

Tie-rod C_6 and C_7.

Here $P = 3,400$ lbs.,

and $2r = \sqrt{\dfrac{4 \times 3400}{3\cdot1416 \times 11200}}$

$= \cdot625.$

log 4	$= 0\cdot60206$
log 3400	$= 3\cdot53147$
	$4\cdot13353$
log denominator	$= 4\cdot54636$
	$2)\,\bar{1}\cdot58717$
log ·625	$= \bar{1}\cdot79358$

Make tie-rods C_6 and C_7 $\frac{5}{8}''$ diameter.

Abstract of Scantlings.

Make—

Principal rafters, $4\frac{1}{2}'' \times 4\frac{1}{2}'' \times \frac{1}{2}''$ T-iron.
Struts DG & FJ, $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{8}''$ L-iron.
" EH, $2'' \times 2'' \times \frac{1}{2}''$ "
Tie-rod AG, ...$1\frac{5}{8}''$ round iron.
" GH, ...$1\frac{1}{2}''$ "
" HL, ...$1\frac{1}{8}''$ "
" HJ, ...$1\frac{1}{8}''$ "
" JC, ...$1\frac{1}{4}''$ "
" GE, EJ, $\frac{5}{8}''$ "

From Table I. it is seen that with the assumed value of h a section $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{8}''$ has the area required.

Make struts A_5 *and* A_7 $1\frac{1}{2}'' \times 1\frac{1}{2}'' \times \frac{1}{8}''$.

Strut A_6.

Compression on strut = 4,200 lbs.

Assume $h = 1{\cdot}50$.

Then $R = \dfrac{6{\cdot}5 \times 12}{1{\cdot}50} = 52$.

Then Table II., $c_1 = 4{,}713$ lbs. and $S = \dfrac{4200}{4713} = {\cdot}89$.

From Table I. it is seen that a section $2'' \times 2'' \times \frac{1}{2}''$ has this area and the assumed value of h.

Make strut A_6 $2'' \times 2'' \times \frac{1}{2}''$.

From Formula IV., $P = S \times t$.

Tie-rod C_1.

Here $P = 23{,}800$ lbs., and

$t = 11{,}200$ lbs., (Table IV.)

Then $S = \dfrac{23800}{11200}$

and $2r = \sqrt{\dfrac{4 \times 23800}{3{\cdot}1416 \times 11200}}$

$= 1{\cdot}65$.

log 4	= 0·60206
log 23800	= 4·37657
	4·97863
log 3·1416	= 0·49715
log 11200	= 4·04921
	4·54636
Subtract	2)0·43227
log 1·65	= 0·21613

Make tie-rod C_1 $1\frac{5}{8}''$ *diameter.*

Tie-rod C_2.

Here $P = 20{,}500$ lbs.,

and $2r = \sqrt{\dfrac{4 \times 20500}{3{\cdot}1416 \times 11200}}$

$= 1{\cdot}52$.

log 4	= 0·60206
log 20500	= 4·31175
	4·91381
log denominator	= 4·54636
	2)0·36745
log 1·52	= 0·18372

Make tie-rod C_2 $1\frac{1}{2}''$ *diameter.*

Tie-rod C_3.

Here $P = 11{,}400$ lbs.,

and $2r = \sqrt{\dfrac{4 \times 11400}{3{\cdot}1416 \times 11200}}$

$= 1{\cdot}13$.

log 4	= 0·60206
log 11400	= 4·05690
	4·65896
log denominator	= 4·54636
	2)0·11260
log 1·13	= 0·05630

Make tie-rod C_3 $1\frac{1}{8}''$ *diameter.*

Tie-rod C_4.

Here $P = 9{,}610$ lbs.,

and $2r = \sqrt{\dfrac{4 \times 9610}{3{\cdot}1416 \times 11200}}$

$= 1{\cdot}04$.

log 4	= 0·60206
log 9610	= 3·98272
	4·58478
log denominator	= 4·54636
	2)0·03842
log 1·04	= 0·01922

Make tie-rod C_4 $1\frac{1}{8}''$ *diameter.*

See Table, page 104, and
Make common rafters $2\frac{3}{4}'' \times 4\frac{1}{2}''$.

Purlins.

2 log 7·5	= 1·75012
log 1860	= 3·26951
	5·01963
log 145	= 2·16136
log 722	= 2·85827

$$W = 7\tfrac{1}{2} \times 7\tfrac{1}{2} \times 33\tfrac{1}{15}$$
$$= 1{,}860 \text{ lbs.}$$

Deflection—

$$bd^3 = \frac{WL^2}{145}$$
$$= \frac{1860 \times 7{\cdot}5^2}{145} = 722.$$

See Table, page 104, and
Make purlins $4\frac{1}{4}'' \times 5\frac{1}{2}''$.

Principal Rafters.

The weight of roof covering is distributed as follows:—$\frac{1}{4}$ at E, $\frac{1}{2}$ at H, and $\frac{1}{4}$ at C.

Now weight of single Allahabad tiling (Table III.)	= 17 lbs.
Wind pressure, the normal component, taken as acting vertically (page 99),	= 18 lbs.
Total	= 35 lbs.

Then $W = 35 \times 15 \times 7\frac{1}{2} = 3{,}950$ lbs.

Now the compression on the two principal rafters being entirely due to the weight acting at H, are necessarily equal to each other.

L sin 26° 30′	= 9·64950
log 4	= 0·60206
	0·25156
log 3950	= 3·59659
log 2220	= 3·34503

Resolve vertically

and $2c_1 \cos \text{EHG} = \dfrac{W}{2}$

$$\text{or } c_1 = \frac{3950}{4 \times \sin 26^\circ\, 30'}$$
$$= 2{,}220 \text{ lbs.,}$$

and $S = \dfrac{4\,P}{c}$, Formula V.

Here $c = 700$, Table III.,

$$\text{and } S = \frac{4 \times 2220}{700} = \frac{8880}{700} = 12{\cdot}6.$$

Make principal rafter $3\frac{1}{2}'' \times 3\frac{1}{2}''$.

EXAMPLE VIII. VERANDAH ROOF. *(Plates V. and VI.)*

A Roof has to be constructed to the verandah of a family quarter: the arrangement of the timber being that shown in Plates XXXIX., XL. *The principal rafters are 7′ 6″ apart, and the roof covering is single Allahabad tiling; the wood used is deodar. The width of the verandah is* 12 *feet. Common rafters* 2′ 6″ *apart. Width of end verandah* 10 *feet. Slope of* 12-*foot verandah roof,* 1 *in* 2.

Spans of verandah roofs = 13′ 6″ and 11′ 6″ *respectively.*

Projection at eaves = 2 *feet from centre of Bressemer, in* 12-*ft. verandah.*

A. 12-FOOT VERANDAH.

(See Plate V., Fig. i.)

Construction of Diagram.

Make AB $= 12' + 9'' + 9'' + 2' = 15'6''$.

Draw BC at right angles to AB and $= \frac{1}{2}$ AB.

Join AC.

Make AD = 2 feet, and draw perpendicular DE.

Draw horizontal line EF, and bisect it in G.

Erect perpendicular GH, and join HF.

Then—

EH and HF are *principal rafters.*

EF is the *tie-rod.*

AC is *common rafter.*

Battens.

$W = 1 \times \overline{2\frac{1}{2} \times 33}$

$= 82$ lbs.

Deflection—Formula III.—

For deodar $bd^3 = \dfrac{WL^2}{145}$

$= \dfrac{82 \times 2\frac{1}{2}^2}{145} = 3{\cdot}5.$

log 2·5	= 0·39794
	2
	0·79588
log 82	= 1·91381
	2·71969
log 145	= 2·16136
log 3·5	= 0·55833

See Table, page 104, and *Make battens* $1\frac{1}{2}'' \times 1\frac{1}{2}''$.

Common Rafters.

$W = 2\frac{1}{2} \times \overline{7\frac{1}{2} \times 33}$

$= 618$ lbs.

Deflection—

$bd^3 = \dfrac{WL^2}{145}$

$= \dfrac{618 \times 7\frac{1}{2}^2}{145} = 240.$

log 7·5	= 0·87506
	2
	1·75012
log 618	2·79098
	4·54110
log 145	= 2·16136
log 240	= 2·37974

log sin 30° 30′	$= \bar{1}\cdot70497$
	$\cdot58$
	563976
	352485
	$\cdot4088826$
	$\cdot58$
	$\cdot1711174$
Subtract	$= \bar{1}\cdot8288826$
log 60	$= 1\cdot77815$
log 40·5	$= 1\cdot60703$

Normal wind pressure

$= \text{P} \sin \theta^{1\cdot84 \cos \theta - 1}$, page 98,

and P = 60 lbs.

Then $\text{P}_n = 40\cdot5$ lbs., but as roof is a light one half this, *i.e.*, 20 lbs., may be taken ; and total normal pressure = 35 lbs. nearly.

Battens.

log 2·5	$= 0\cdot39794$
	2
	$0\cdot79588$
log 88	$= 1\cdot94448$
	$2\cdot74036$
log 145	$= 2\cdot16136$
log 3·79	$= 0\cdot57900$

$\text{W} = 1 \times 2\tfrac{1}{2} \times 35 = 88$ lbs.

Deflection—Formula III.—

For deodar $bd^3 = \dfrac{\text{WL}^2}{145}$

$= \dfrac{88 \times 2\frac{1}{2}^2}{145} = 3\cdot79.$

See Table, page 104, and

Make battens, $1\tfrac{1}{4}'' \times 1\tfrac{1}{2}''$.

Common Rafters.

log 6·7	$= 0\cdot82607$
	2
	$1\cdot65214$
log 585	$= 2\cdot76715$
	$4\cdot41929$
log 145	$= 2\cdot16136$
log 188	$= 2\cdot25793$

$\text{W} = 2\tfrac{1}{2} \times 6\cdot7 \times 35 = 585$ lbs.

Deflection—Formula III.—

For deodar $bd^3 = \dfrac{\text{WL}^2}{145}$

$= \dfrac{585 \times 6\cdot7^2}{145} = 188.$

See Table, page 104, and

Make common rafters $2\tfrac{1}{2}'' \times 4\tfrac{1}{4}''$.

Principal Rafters.

log sin 30° 30′	$= 9\cdot70497$
log 4	$= 0\cdot60206$
	$0\cdot30703$
log 3340	$= 3\cdot52374$
log 1640	$= 3\cdot21671$

Taking the distribution of weight as before,

$\text{W} = 33 \times 13\tfrac{2}{5} \times 7\tfrac{1}{2} = 3{,}340.$

And as before—

$c_1 = \dfrac{3340}{4 \times \sin 30^\circ\ 30'}$

$= 1{,}640$ lbs.,

and $\text{S} = \dfrac{4\ \text{P}}{c}$, Formula V.

Here $c = 700$, Table III.,

and $\text{S} = \dfrac{4 \times 1640}{700} = \dfrac{6560}{700} = 9\cdot37.$

Make principal rafters $3'' \times 3''$.

Tie-rod.

L cos 26° 30′	= 9·95166
log 2220	= 3·34503
log 4	= 0·60206
	3·89875
log 3·1416	= 0·49715
log 11200	= 4·04921
	4·54636
Subtract	2) $\bar{1}$·35239
log ·477	= $\bar{1}$·67619

Resolve horizontally

and $T = c_1 \cos HFG$,

$= 2220 \cos 26° 30'$

and $2r = \sqrt{\dfrac{4 \times 2220 \cos 26° 30'}{3{\cdot}1416 \times 11200}}$

$= {\cdot}477.$

Make tie-rod $\frac{1}{2}''$ diameter.

B. 10-foot Verandah.

(See Plate V., Fig. ii.)

Construction of Diagram.

Make EF $= 10' + 9'' + 9'' = 11{\cdot}6$.

Erect perpendiculars KL and FC, KF being = 9 inches.

Now the two verandahs cut the wall at the same level.

Make KL = KL in *Plate* V., *Fig.* i.

And the eaves terminate at the same level.

Make ED = ED in *Plate* V., *Fig.* i.

Draw horizontal line DA.

Join EL, and produce it to A and C.

Bisect EC in H, and join HF.

Draw perpendicular HG.

Then—

EH and HF are *principal rafters.*

EF is *tie-rod.*

AC is *common rafter.*

Slope of Roof.

Now slope of roof $= \sin^{-1} \dfrac{CF}{CE}$

$= \sin^{-1} \dfrac{6{\cdot}8}{13{\cdot}4}$

$= \sin^{-1} {\cdot}5074627$

$= 30° 33'.$

Normal Pressure.

log cos 30° 30′	= 9·93530
log 1·84	= 0·26481
log 1·58	= 0·20011

The normal pressure per square foot of single Allahabad tiling

$= 17 \cos \theta$, (Table III.)

$= 17 \cos 30° 30' = 14{\cdot}7$ lbs.

$= \frac{1}{2} \times 13\frac{1}{2} \times 13\frac{1}{2} \times 33 =$ 3,010 lbs.,

and of this, again, half is borne by the hip rafter.

(*See Plate* VI., *Fig.* iv.)

Construction of Elevation of Hip Truss.

Make AB = AO, *Fig.* iii.

Erect perpendicular BE.

With centre A and radius = AO_1 or AO_{11} (*Fig.* iii), describe a circle cutting BE in E.

Join AE.

Bisect AE in F, and join FB.

Then—

AF and FB are *principal rafters.*

AB is *tie-rod.*

W = Total weight on Hip Truss.

$$W = \frac{1}{2}(W_1 + W_2)$$

$$= \frac{2840 + 3010}{2} = \frac{5850}{2}$$

$$= 2{,}925 \text{ lbs.}$$

Angle of Inclination of Rafters.

$$\text{Sin EAB} = \sin^{-1}\frac{EB}{AE}$$

$$= \sin^{-1}\frac{6\cdot7}{19}$$

$$= \sin^{-1}\cdot3526316$$

$$= 20^\circ\ 39'.$$

Principal Rafters.

log 4	$= 0\cdot60206$
log sin 20° 39′	$= 9\cdot54705$
	$0\cdot14911$
log 2925	$= 3\cdot46538$
log 2070	$= 3\cdot31627$

As before—

$$c_1 = \frac{2925}{4 \times \sin 20^\circ\ 39'}$$

$$= 2070,$$

and $S = \frac{4P}{c}$, Formula V.,

and here $c = 700$, Table III.

Then $S = \frac{4 \times 2070}{700} = \frac{8280}{700} = 11\cdot85.$

Make principal rafter $3\frac{1}{2}'' \times 3\frac{1}{2}''$.

Tie-rod.

log cos 30° 30′	= 9·93530
log 1640	= 3·21671
log 4	= 0·60206
	3·75407
log denominator	= 4·54636
	2)$\bar{1}$·20771
log 403	= $\bar{1}$·60385

As before—

$$2r = \sqrt{\frac{4 \times 1640 \times \cos 30^\circ 30'}{3 \cdot 1416 \times 11200}}$$

$$= \cdot 403$$

Make tie-rod $\frac{3}{8}''$ diameter.

C. Hip-Rafter.

(*See Plate* VI., *Fig.* iii).

Construction of diagram.

Draw a plan of the angle of the verandah.

Dotted lines—Centre lines of walls.

Firm lines—Principal rafters.

Thin lines—Common rafters and purlins.

Chain-dotted lines—Plans of lines turned into plane *of paper.*

Weight on Hip Truss.

To turn the triangle AOB into the plane of the paper.

Make $BO_1 = EC$ in *Fig.* i, and join AO_1.

Then AO_1 is the length of slope of the hip.

Let W_1 = vertical weight on triangle AO_1B,

$= \frac{1}{2} AB \times BO_1 \times 33$

$= \frac{1}{2} \times 11\frac{1}{2} \times 15 \times 33 = 2{,}840$ lbs., and of this half is borne by the hip rafter.

Similarly to turn the triangle AOE_2, into the plane of the paper.

Make $EO_{11} = EC$ in *Fig.* ii.

Join AO_{11}.

Let W_2 = vertical weight on triangle $AO_{11}E$

$= \frac{1}{2} \times AE \times EO_{11} \times 33$

D. Coupled Rafters.

These are very common in roofs of out-houses, covered passages, and as planked trusses in small buildings in the Hills. The roof covering rests uniformly on the rafters, either as battens or planking, and thus causes them to be under complex strain, *i.e.*, a direct thrust and transverse strain.

Example VIII. D.

A roof, as shown on Plate XLVI., *has to be constructed over a Servant's quarter. The principal rafters are* $3\frac{1}{2}$ *feet apart, and the roof covering is single Allahabad Tiling; the wood used is deodar. The battens, 1 foot apart, rest direct on the principal rafters. The slope of the roof is 1 in 2.*

Battens.

log 2	$= 0{\cdot}30103$
log 119	$= 2{\cdot}07554$
log 3·5	$= 0{\cdot}54406$
	2
	$1{\cdot}08812$
	$3{\cdot}44469$
log 3	$= 0{\cdot}47712$
log 145	$= 2{\cdot}16136$
	$2{\cdot}63848$
	$0{\cdot}80621$
log 6·4	$= 0{\cdot}80618$

$W = 1 \times 34 \times 3\frac{1}{2} = 119$ lbs.

Deflection—Formula III., for deodar in case of fixed beams,

$$bd^3 = \frac{2}{3} \times \frac{WL^2}{145} = \frac{2}{3} \times \frac{119 \times 3\frac{1}{2}^2}{145}$$

$$= 6{\cdot}4.$$

Make battens $1\frac{1}{4}'' \times 1\frac{3}{4}''$, *see* Table, page 104.

Principal Rafters.

log 119	$= 2{\cdot}07554$
log 2	$= 0{\cdot}30103$
log sin 26° 30′	$= 9{\cdot}64944$
	$9{\cdot}95047$
	$2{\cdot}12507$
log 185	$= 2{\cdot}12383$

As in Example VIII. A, resolving vertically we have for *direct thrust*—

$$W = 2\, C_1 \cos EHG$$

$$\text{or } C_1 = \frac{119}{2 \sin 26^\circ\, 30'} \times 7$$

$$= 133 \times 7$$

$$= 931 \text{ lbs.}$$

The principal rafters are supported by battens at 1 foot intervals so that length is between 1 and 8 times the least sectional dimensions. Then Formula V., $P = S \times c$.

For deodar $c = 700$ (Table IV.)

$$\text{Then } S = \frac{P}{c} = \frac{931}{700} = 1{\cdot}33 \;\ldots\ldots\ldots\; \text{(i)}.$$

Tie-rod.

log cos 20° 39′	= 9·97205
log 2070	= 3·31627
log 4	= 0 60206
	3·89038
log denominator	= 4·54636
	2) $\overline{1}$·34402
log ·470	= $\overline{1}$·67201

As before—

$$2r = \sqrt{\frac{4 \times 2070 \times \cos 20^\circ\ 39'}{3{\cdot}1416 \times 11200}}$$

$$= {\cdot}470.$$

Make tie-rod ½″ diameter.

Common Rafters and Purlins lying on Hip Truss.

Make the common rafters and purlins the same as in their respective verandahs on either side of the hip truss.

Example IX.

Hammer-Beam Truss.

A roof is to be constructed over the nave of a Church built in the gothic style of architecture. The width of the nave is 30 feet; the slope of the roof is to be 45°; the roof covering is to consist of 22 B. W. G. plain sheet iron laid on the Naini Tal pattern on $1\frac{1}{2}$-inch deodar planking, on purlins at $5\frac{1}{4}$ feet central intervals, which again rest on hammer-beam trusses spaced at 9 feet central intervals. The woodwork is to be deodar, and the hammer-beam trusses of the form shown in Plate VII., Fig. i.

<u>*Construction of Truss.*</u>

See Plate VII., *Fig.* i.

Set off BB′ equal to 30 feet. Bisect it in E′, and draw E′E perpendicular to BB′. Make EE′ equal to $\frac{BB'}{2}$, and join BE and B′E.

Bisect BE and B′E in D and D′, and join DD′.

From D and D′ draw DC and D′C′ perpendicular to BB′ cutting it in C and C′. From B and B′ draw BA and B′A′ perpendicular to BB′, and make BA = BA′ = DC = D′C′. Draw CG and FH perpendicular to BE, and C′G′ and FH′ perpendicular to B′E. Join FE and draw the curved struts AC, A′C′ and CF, C′F. The truss is then complete.

In this truss BC, B′C′ are horizontal ties. AC, A′C′ are struts curved for architectural effect. CF, C′F are curved stays or stiffeners to provide against irregularities of the load. The upper portion DED′ is a king-post truss, and CG, CG′ are struts supporting the principal rafter at G, G′ where purlins come.

log 119	$= 2{\cdot}07554$
log 49	$= 1{\cdot}69019$
	$3{\cdot}76573$
log 5830	$= 3{\cdot}76566$

Transverse Strain—For deodar

$$bd^2 = \frac{\mathrm{WL}}{100} = \frac{34 \times 3\tfrac{1}{2} \times 7 \times 7}{100}$$

$$= \frac{119 \times 49}{100} = 58{\cdot}31 \text{ ....(ii).}$$

Then $b = 0{\cdot}27$, $d = 5$ satisfies ......(i).

$b = 2{\cdot}36$, $d = 5$ „ ......(ii).

Add the two values of b and *make principal rafters* $2\frac{3}{4}'' \times 5''$.

N.B.—For the theory involved in the above method, *see* "Roorkee Manual of Applied Mechanics," Vol. I., pages 281—287.

or $R = \frac{W}{6} + \frac{T}{3}$ .... (1).

If the tie CF be considered omitted, then $R = \frac{W}{6}$, and the diagram, *Fig.* 4, can be drawn for the truss, which gives a thrust on C′F $= \frac{7}{6}$ W_1 (*am* in diagram). This is excessive, and there is no good reason for supposing that CF will not help as a tie to relieve this strain. Assume $R = \frac{W_1}{4}$, then equation (1),

$$\frac{W_1}{4} = \frac{W_1}{6} + \frac{T}{3},$$

$$\text{or } \frac{T}{3} = \frac{W_1}{4} - \frac{W_1}{6} = \frac{W_1}{12}$$

$$\text{or } T = \frac{W_1}{4} = R,$$

which is found to be the case by the diagram that can now be drawn of the stresses of the truss as follows :—

Now $W_1 = 21 \times 9 \times 27 = 5{,}150$ lbs.

On a scale of 1,000 lbs. = 1 inch draw, *see Fig.* 5, *bc* parallel to R and equal to $\frac{W_1}{4} = 1{,}287$ lbs., from *b* and *c* draw *ba* and *ca* parallel to BA and CA respectively. Then the diagram of stresses at A is *bcab;* at B, *abdea;* at G, *dfged*; at C, *fhijkf*, where *kf* equals strain on CF or T above, which equals *a c* or R as stated above ; at D, *hlmnoh;* at H, *onpqo;* at E, *lrml;* at F, *hlmsth.*

From this diagram it is apparent that there is no stress in the principal rafter EB′, *vide* diagram for E, or in any of the other parts of the truss, except FC′ and A′C′, in which there is a thrust of $\frac{3W_1}{4}$ = R′ which thus

Note.—*Most officers hold different views regarding the best way of calculating the strains in a hammer-beam truss. The following solution has no pretension to be mathematically correct, but it is considered to be sufficiently accurate to answer all practical purposes. It is doubtful, if a strictly mathematical solution be possible.*

Vertical or Permanent load.

First ; consider only the vertical or permanent load, which on one half the truss say $= W$.

This acts as shown in *Fig.* 1 as under, $\frac{W}{8}$ at E, $\frac{W}{4}$ at H, $\frac{W}{4}$ at D, $\frac{W}{4}$ at G, and $\frac{W}{8}$ at B. The reaction of the wall may be resolved vertically and horizontally. The vertical component R $= W$, and the horizontal component T has to be determined hereafter.

Now, weight of 22 B. W. G. plain sheet iron including lappage $= 1{\cdot}40$ lbs. per square foot.

$1\frac{1}{2}''$ deodar planking $= \frac{40}{8} = 5$ lbs. per square foot. Therefore weight of roof-covering $= 6{\cdot}4$ lbs. per square foot.

Then—

$$\begin{aligned} W &= 6{\cdot}4 \times 21 \times 9 \times 1 \text{ (roof-covering)} \\ &\quad + 3\tfrac{1}{2} \times 9 \times 40 \times \frac{4 \times 6}{144} \text{ (purlins)} \\ &\quad + 2 \times 21 \times 40 \times \tfrac{1}{5} \text{ (say, truss)} \\ &= 1210 + 210 + 337 \\ &= 1{,}757. \end{aligned}$$

Now assuming that the curved stiffeners CF, C′F can be neglected, the truss may be considered to be a king-post truss DED′ supported by two com-

Make principal rafter 4″ × 3″.

Curved Strut AC.

Here P = 4725,

$$S = \frac{2 \times 4725}{700} = \frac{9450}{700} = 13{\cdot}5,$$

but as strut is curved make

S = 24, or

Make curved strut AC 4″ × 6″.

Struts AB, DF.

As before—

$$S = \frac{2\ P}{c}$$

Here P = 2,920 lbs.,

$$\text{and } S = \frac{2 \times 2920}{700} = \frac{5840}{700}$$

$$= 8{\cdot}34.$$

Make struts AB, DF 3″ × 4″ *for architectural reasons.*

Curved Strut CF.

Here P = 3800,

$$\text{and } S = \frac{2 \times 3800}{700}$$

$$= 12{\cdot}3,$$

but as strut is curved make

S = 24, or

Curved strut CF 4″ × 6″.

Struts CG *and* HF.

Here P = 1595

$$\text{and } S = \frac{2 \times 1595}{700}$$

$$= 4{\cdot}6.$$

Make struts CG, FH 4″ × 3″ *for architectural reasons.*

Tie BC.

Formula IV.—

$$P = S \times t.$$

Here P = 1350, t = ·700.

$$\text{Then } S = \frac{1350}{700} = 2{\cdot}0.$$

Make BC 4″ × 3″ *for architectural reasons.*

Temporary Load or Wind Pressure.

The normal wind pressure on a roof sloping $\frac{1}{1}$ is, *see* page 98, 54 lbs. per square foot. But as the roof is a light one, this may be reduced according to the rule on page 99 to 27 lbs. per square foot.

Let W_1 = total normal wind pressure on one side of the roof.

Then $\frac{W_1}{8}$ acts at B, $\frac{W_1}{4}$ at C, $\frac{W_1}{4}$ at D, $\frac{W_1}{4}$ at H, and $\frac{W_1}{8}$ at E.

A hammer beam truss is secured to the walls at A, B, A′, B′, while the parts AB and A′B′ rest against the walls. The reactions of the walls at these points are indeterminate depending on accuracy of construction; and as different assumptions regarding their mode of action give rise to very different diagrams of stresses, it is believed a mathematically accurate diagram cannot be drawn. With the wind acting as shown on *Fig.* 2, it is evident that most of the reaction against it will be exerted by the wall at A′B′; while of the part exerted by AB, that at B cannot be great, as the wall there has little holding power, and it may be assumed without much risk of error that it acts at A.

Now by the method of sections if the truss be cut by a plane passing through D and CF, to sustain the lower part of the truss thus cut off there is the thrust T_1 at D, and the strain of the tie CF = T acting along this bar; taking moments round D,

$$R \times 3 = \frac{W}{8} \times 2 + \frac{W}{4} \times 1 + T \times 1$$

Trussed Beams.

The following are given as two simple Examples for a guide in cases where it is necessary either to truss old beams which have unduly deflected; or where, in a new building, it is required to use a beam with a smaller scantling than will carry the load, either in order not to place the beams too close together, or in cases where it is not convenient to use beams of the full calculated scantling.

Example X. (*Plate* VIII.)

Let AB *be the beam, with a span of* 16 *feet, the* total *distributed load being* 20,000 *lbs.; for one of the reasons given above, it is required to truss the beam with a single strut of a length* $= \frac{1}{12}$*th of the span.*

Length of strut $= \frac{1}{12} \times 16$ *feet* $= 16$ *inches.*

(*See Plate* VIII., *Fig.* i).

Construction of Diagram of central lines of struts and ties.

Make AB = 16 feet.
Bisect AB in C.
Drop perpendicular CD = 16 inches.
Join AD and DB.
Then—
CD is a *strut.*
AD and DB are *tie-rods.*

Now, of the distributed load, $\frac{1}{4}$ is borne at A, $\frac{1}{2}$ at C, and $\frac{1}{4}$ at B.

---

c = *Compression on Strut* CD.

The point C is in equilibrium.
Resolve along CD.

$$\therefore c = \tfrac{1}{2} \text{W}$$
$$= 10{,}000 \text{ lbs.}$$

Calculate scantling by Formula V.

---

t = *Tension of Tie-rods* AD *and* DB.

Again the point D is in equilibrium.
By symmetry—
Tension on AD = tension on BD.
Resolve along CD.

$$c = 2t \cos \text{ADC}.$$

acts at A′. This if checked by the method of sections through D′ will be found correct, and as it makes the tie CF bear $\frac{W_1}{4}$ in tension, and the strut C′F $\frac{3W_1}{4}$ in compression, it may be regarded as a satisfactory solution of the problem.

By measuring off the lengths of the different lines in the diagrams, *Figs.* 3 and 5, a Table of Maximum Stresses on the different parts of one-half the truss can be drawn up as follows :—

Part of truss.	Permanent load.	Wind on left.	Wind on right.	Maximum stress on each part of truss.
AB	$+\frac{5}{8}W$	$+\frac{1}{4}W_1\sqrt{2}$	nil	$+\frac{5}{8}W+\frac{1}{4}W_1\sqrt{2}=+2{,}920$ lbs.
AC	$+\frac{3}{8}W\sqrt{2}$	$-\frac{1}{4}W_1$	$+\frac{3}{4}W_1$	$+\frac{3}{8}W\sqrt{2}+\frac{3}{4}W_1=+4{,}725$,,
BC	$-\frac{1}{4}W$	$-\frac{1}{8}W_1\sqrt{2}$	nil	$-\frac{1}{4}W-\frac{1}{8}W_1\sqrt{2}=-1{,}350$,,
BG	$+\frac{1}{2}W\sqrt{2}$	$+\frac{3}{8}W_1\sqrt{2}$	,,	$+\frac{1}{2}W\sqrt{2}+\frac{3}{8}W_1\sqrt{2}=+3{,}985$,,
CG	$+\frac{1}{8}W\sqrt{2}$	$+\frac{1}{4}W_1$	,,	$+\frac{1}{8}W\sqrt{2}+\frac{1}{4}W_1=+1{,}595$,,
CD	$+\frac{1}{4}W$	$-\frac{1}{8}W_1\sqrt{2}$	,,	$-\frac{1}{8}W_1\sqrt{2}=-\ 910$,,
CF	nil	$-\frac{1}{4}W_1$	$+\frac{3}{4}W_1$	$+\frac{3}{4}W_1=+3{,}800$,,
DF	,,	$+\frac{3}{8}W_1\sqrt{2}$	nil	$+\frac{3}{8}W_1\sqrt{2}=+2{,}750$,,
DH	$+\frac{3}{8}W\sqrt{2}$	$-\frac{1}{8}W_1$	,,	$+\frac{3}{8}W\sqrt{2}=+\ 925$,,
HE	$+\frac{1}{4}W\sqrt{2}$	$-\frac{1}{8}W_1$	,,	$+\frac{1}{4}W\sqrt{2}=+\ 610$,,
EF	$-\frac{1}{4}W$	$+\frac{1}{8}W_1\sqrt{2}$	$+\frac{1}{8}W_1\sqrt{2}$	$+\frac{1}{8}W_1\sqrt{2}=+\ 910$,,
DG	$+\frac{3}{8}W\sqrt{2}$	$+\frac{1}{4}W_1$	nil	$+\frac{3}{8}W\sqrt{2}+\frac{1}{4}W_1=+2{,}210$,,
HF	$+\frac{1}{8}W\sqrt{2}$	$+\frac{1}{4}W_1$	,,	$+\frac{1}{8}W\sqrt{2}+\frac{1}{4}W_1=+1{,}595$,,

Compressions are shown with + sign.
Tensions ,, ,, − ,,

To calculate dimensions of different parts of truss.

Principal Rafters BD.

Length unsupported laterally = BG = 5·25 feet.

Formula V., $S=\frac{2P}{c}$

Here P = 3,985 lbs., c = 700 lbs.

Then $S=\frac{2\times 3985}{700}=\frac{7970}{700}=11{\cdot}40.$

EXAMPLE XI. (*Plate* VIII).

Let AB *be a beam, with a span of* 24 *feet, the* total *distributed load being* 30,000 *lbs. For one of the reasons given above, it is required to truss this beam with two struts, each* $\frac{1}{16}$ *of the span, or* 18 *inches long.*

(*See Plate* VIII., *Fig.* ii).

Construction of Diagram of central lines of struts and ties.

Make AB = 24 feet.
Trisect AB in C and D.
Drop perpendiculars CE and DF, each = 18 inches.
Join AE, EF, and FB.
Then—
CE and DF are *struts.*
AE, EF, and FB are *tie-rods.*

Now of the distributed load, $\frac{1}{6}$ is borne at A, $\frac{1}{3}$ at C, $\frac{1}{3}$ at D, and $\frac{1}{6}$ at B.

---

c = *Compression on Struts* CE *and* DF.

The point C is in equilibrium.
Resolve vertically.

$$\therefore c = \tfrac{1}{3} \times W$$
$$= 10{,}000 \text{ lbs.}$$

---

t = *Tension of Tie-rods* AE *and* BF.

Again the point E is in equilibrium.
By symmetry—
Tension on AE = tension on FB.
Resolve vertically.

$$\therefore t \cos CEA = c.$$
$$\therefore t \times \frac{CE}{AE} = c.$$

But $AE = \sqrt{AC^2 + CE^2}$
$= \sqrt{144 \times 64 + 324}$
$= \sqrt{9540}$

$$\therefore t = \frac{c \times \sqrt{9540}}{18}$$
$$= 54{,}263 \text{ lbs.}$$

$\log c = \log 10000$	$= 4{\cdot}00000$
$\log AE = \frac{1}{2} \log 9540$	$= 1{\cdot}98977$
log numerator	$= 5{\cdot}98977$
$\log CE = \log 18$	$= 1{\cdot}25527$
$\log t = \log 54263$	$= 4{\cdot}73450$

bstract of Scantlings.

Make—

Principal rafters EB,	... 4″ × 3″
Curved struts AC,	... 4″ × 6″
Struts AB, DF,	... 3″ × 4″
Tie BC,	... 3″ × 4″
Struts CG, FH,	... 3″ × 4″
Tie EF,	... 3″ × 4″
Curved stays CF, C′F,	... 4″ × 6″

Calculate purlins as in previous Examples.

The points A, B, A′, B′, must be firmly fixed to the walls by iron cramps, and the walls must be supported by buttresses at A, A′ calculated to resist the maximum thrust at these points.

This is made up of $ad' = \frac{17}{16}W$, *see Fig.* 3, in amount and direction for permanent load; and $R = 1\frac{3}{4} W_1$, *Fig.* 5, for temporary load. The resultant of these two forces will give amount and direction of greatest thrust on walls.

Note—

In making calculations for a truss similar in proportion to the above, it will not be necessary to go through all these elaborate calculations. It will merely be necessary to reconstruct the table of stresses for the altered conditions of W and W_1 in each case, remembering that the proportion between each stress and the load will remain the same in each case.

The dimensions of each part of the truss can then be calculated for the stresses given in the table reconstructed as explained above.

$$= 2t \times \frac{CD}{AD}$$

But $AD = \sqrt{AC^2 + CD^2}$

$= \sqrt{144 \times 64 + 256}$

$= \sqrt{9472}$

$\therefore t = \frac{c \times \sqrt{9472}}{32}$

$= 30,414$ lbs.

log c = log 10000	= 4·00000
$\frac{1}{2}$ log 9472	= 1·98822
log numerator	= 5·98822
log 32.	= 1·50515
log t = log 30414	= 4·48307

Calculate diameter, or side of square, of iron tie-rod by Formula IV.

c_1 = *Compression on Beam* AB.

log t	= 4·48307
log AC = log 96	= 1·98227
log numerator	= 6·46534
log AD = $\frac{1}{2}$ log 9472	= 1·98822
log c_1 = log 30000	= 4·47712

Again the point A is in equilibrium.

Resolve along AB.

$c_1 = t \cos CAD$

$= t \times \frac{AC}{AD}$

$= 30,000$ lbs.

In addition to this however as the load is uniformly distributed there is a transverse strain on AC and CB.

Weight on AC $= \frac{W}{2} = 10,000$ lbs.

Length = 8 feet.

Transverse Strain—Formula III.—

For sál $bd^2 = \frac{WL}{180}$

$= \frac{10000 \times 8}{180} = 444$, (i).

Direct Strain—Formula V.—

For sál $S = \frac{P}{c} = \frac{30000}{1210}$.

(*Note.*—The beam AC is supported laterally by joists at about 1 foot intervals, hence it is a short strut).

Then $S = bd = 24·7$ ....(ii).

See Table, page 106.

Then—

$b = 4·5,\ d = 10$ satisfies equation (i).

$b = 3,\ d = 10$ „ „ (ii).

Make beam AB $7\frac{1}{2}'' \times 10''$.

For the theory of the above, see *Roorkee Manual of Applied Mechanics, Vol. I., Chapter XIII.*

$t_1 =$ *Tension of Tie-rod* EF.

log t, from above	$= 4{\cdot}73450$
log AC = log 96	$= 1{\cdot}98227$
log numerator	$= 6{\cdot}71677$
log AE = $\frac{1}{2}$ log 9540	$= 1{\cdot}98977$
log t_1 = log 53334	$= 4{\cdot}72700$

Resolve horizontally.

$$t_1 = t \cos \text{CAE}$$
$$= t \times \frac{\text{AC}}{\text{AE}}$$
$$= 53{,}334 \text{ lbs.}$$

$c_1 =$ *Compression on Beam* AC.

Again the point A is in equilibrium.
Resolve horizontally.

$$c_1 = t \cos \text{CAE}$$
$$= t_1 \text{ (from above)}$$
$$= 53{,}334 \text{ lbs.}$$

Calculate dimensions as in previous Examples.

usually be best to accept the tender of some known and reliable Contractor, even if it be not the lowest.

7. A plan often adopted with success, is not to allow an unknown or unreliable Contractor to tender for an important work, but to make it a rule to accept the lowest tender from among those who have been granted permission to send in tenders.

8. As soon as the tender has been accepted, the Contractor should be given written notice of the fact in a book kept for the purpose. At the same time he should be directed to forward his security deposit, and be informed of the date on which work is to commence. His signature and that of the Sub-Divisional officer concerned should be recorded in the book against this notice.

9. Contractors are bound to make use of the articles on the Government stock as far as possible. The Contractor is responsible for making himself acquainted with the materials on Government stock, and the rates at which such materials will be issued to him before making his tender for the contract. The stock prices of materials issued to him will be deducted from his bill, or he will pay the money in cash as may be directed by the Executive Engineer.

10. No women are to be employed on any work within the lines of British Troops while those lines are occupied by them.

11. Written authority signed by the Executive Engineer or the Subordinate in charge of the work must be produced for any deviation from the measurements or specifications of an estimate. If no such authority can be produced, then the Contractor will be held responsible for the deviation. The measurements referred to are those in the drawings; those in the estimates are for purposes of calculations and not for the information of Contractors.

PART IV.

CONTRACTS, ABSTRACTS OF ESTIMATES. &c.

I. The above Estimate includes charges for work Establishment, Tools and Plant, &c.

II. The work will be executed by Petty Contract, and will be completed within 9 months.

III. Funds are not allotted in Budget for current year for this work, and an appropriation is solicited to the extent of Rs. 5,238.

IV.	Total of Estimate, ...	Rs.	5,238
	Deduct values of Stock issues, ...	,,	3,000
	Balance cash required, ...	,,	2,238

CONTRACTS.

1. Executive Engineers are advised to carry out all works in their Divisions by contract with respectable natives ; not only are works executed as a rule more cheaply in this manner than by daily labour, but the supervising establishment is thereby saved a large amount of extra work.

2. Tenders for all works proposed for execution by contract should be invited in the most public manner possible. This is usually done in practice by posting *ishtihars* on the prescribed form outside the Executive Engineer's office, on public notice boards, and by sending copies to the local Civil officers. The date for the reception of Contractors' tenders should be stated, as well as the date on which the work is to be commenced and finished.

3. While the *ishtihars* are out, the estimate and plans for the work will be open for the inspection of all persons proposing to submit tenders, and every assistance should be given to the latter, to enable them to thoroughly understand the details of the work, for the execution of which they propose to tender.

4. All persons, who submit a tender, should fill in the prescribed form, and when forwarding the tender, it must invariably be accompanied by the necessary earnest money.

5. Tenders should, as far as possible, be opened in the presence of all the tenderers, and the result at once made known to them.

6. It is difficult to lay down any fixed rule for guidance in accepting tenders. There is little or no doubt, that the practice of accepting the lowest tender in all cases, induces Contractors to tender at lower rates, and consequently cheapens work. On the other hand many failures of bad Contractors occur under such a system, Perhaps the best plan is to accept the lowest tender, (when nothing very bad is known against this tenderer), in all cases where there is plenty of time to remedy the effects of failure, such as in annual repairs, &c. But in cases where a work has to be pushed on energetically, and completed within a certain date, it will

(Specimen).

Abstract of Estimate for Subsidiary Buildings to Family Quarters, Agra.

For 4 blocks, Class II., to accommodate 34 Families.

Items.	Rate.	Unit.	Cook-House for Five Families. For one.	Cook-House for Five Families. For two.	Cook-House for Five Families. Cost.	Cook-House for Four Families. For one.	Cook-House for Four Families. For six.	Cook-House for Four Families. Cost.	Latrine for Men. For one.	Latrine for Men. For two.	Latrine for Men. Cost.	Latrine for Women. For one.	Latrine for Women. For four.	Latrine for Women. Cost.	Covered Passage. For one.	Covered Passage. For four.	Covered Passage. Cost.	Grand Total. Quantity.	Grand Total. Cost.
					RS.			RS.			RS.			RS.			RS.		RS.
1. *Earthwork.*		c. ft.																	
i. Excavation, ...	0 4 0	100	1,096	2,192	5	877	5,262	13	515	1,030	3	580	2,320	6	477	1,908	5	12,712	32
ii. Plinth filling, ...	0 4 0	”	191	382	1	153	918	2	48	96	1	53	212	1	...	...	...	1,608	5
																		14,320	37
Average rate for Earthwork, ...																			
2. *Concrete.*	15 0 0	”	406	812	122	353	2,118	318	200	400	60	222	888	133	...	...	...	4,218	633
3. *Brickwork.*																			
i. Foundation, ...	23 0 0	”	411	822	189	357	2,142	493	187	374	86	209	836	192	521	2,084	479	6,258	1,439
ii. Plinth, ...	24 0 0	”	200	400	96	165	990	238	67	134	32	72	288	69	...	...	...	1,812	435
iii. Superstructure, ...	25 0 0	”	1,484	2,968	742	1,229	7,374	1,844	462	924	231	507	2,028	507	...	...	...	13,294	3,324
iv. Cornices, ...	29 0 0	”	35	70	20	33	198	57	18	36	10	18	72	21	...	...	...	376	108
v. Arches, ...	27 0 0	”	110	220	59	104	624	168	21	42	11	21	84	23	...	...	...	970	261
																		22,710	5,567
Average rate for Brickwork, ...	24 8 3	”																	
4. *Cut Stonework.*																			
i. Pillars, ...	1 8 0	c. ft.	11	22	33	11	66	99	...	...	...	...	...	...	160	640	960	728	1,092
ii. Corbel tables, ...	1 0 0	”	63	126	126	52	312	312	4	8	8	4	16	16	...	...	...	462	462
																		1,190	1,554
Average rate for Cut Stonework,	1 4 10	”																	

(Specimen).

Abstract of Estimate for Constructing Quarters for Butcher-Sergea[illegible] Allahabad.

Items.		Quantity.	RATE. Cost.	Per	AMOUNT. Of each.	Total.	Grand Total.
1. Earthwork, ...	c. ft.	4,155	-/8/-	%	21	21	
2. Concrete, ...	"	1,926	19/-/-	"	366	366	
3. Brickwork, including arches,	"	6,215	28/-/-	"	740	740	
4. Ashlar, ...	"	236	1/8/-	c. ft.	354	354	
5. Flooring—							
i. Earthwork, ...	"	1,461	-/8/-	%	7		
ii. Concrete, ...	"	279	19/-/-	"	53		
iii. Flagging, ...	s. ft.	1,079	20/-/-	"	216		
Average rate for Flooring,	"	1,079	24/10/5	"	276	276	
6. Plaster, ...	"	3,581	4/-/-	"	143	143	
7. Roofing—							
i. Woodwork, ...	c. ft.	192	5/-/-	c. ft.	960		
ii. Ironwork, ...	lbs.	673	25/-/-	cwt.	150		
iii. Varnishing, ...	s. ft.	1,287	3/-/-	%	39		
iv. Tiling, double, ...	"	1,391	20/-/-	"	278		
v. Whitewashing, ...	"	1,391	-/6/-	"	5		
Average rate for Roofing, ...	"	1,391	102/15/1	"	1,432	1,432	
8. Doors and Windows—							
i. Woodwork, ...	c. ft.	28	5/-/-	c. ft.	140		
ii. Joinery, ...	s. ft.	258	1/4/-	s. ft.	323		
iii. Ironwork, ...	lbs.	219	25/-/-	cwt.	49		
iv. { Varnishing, ...	s. ft.	308	3/-/-	%	9		
{ Painting, ...	"	243	3/-/-	"	7		
Average rate for Doors and Windows, ...	"	258	2/-/8	s. ft.	528	528	
9. Punkahs—							
i. Joists, ...	c. ft.	2	5/-/-	c. ft.	10		
ii. Framing, including hooks, ropes, &c.,	s. ft.	20	2/-/-	s. ft.	40		
iii. Blocks with pulleys,	No.	2	2/-/-	each	4		
Average rate for Punkahs,	s. ft.	20	2/4-	s. ft.	54	54	
10. Whitewashing,... ...	"	4,156	-/6/-	%	16	16	
11. Bureewashing,... ...	"	1,704	-/6/-	"	6	6	
12. Padlock, hasp, and staple,	No.	1	2/8/-	each	3	3	
13. Dressing ground and surface drains, ...						50	4,989
Add Contingencies, at 5 per cent.							249
Grand Total Rupees, ..							5,238

Cost of each supl. ft. of plinth area covered $\frac{5238}{1285} = 4{\cdot}07$, or Rs. 4-1-2 [illegible]

[*N.B.*—This is merely given as an Example as to form in details, but [illegible] any building should not exceed Rs. 3-8-0 per superficial foot of plinth [illegible] unless exceptional and good reason can be given].

Items.	Rate.			Unit.	Cook-House for Five Families.			Cook-House for Four Families.			Latrine for Men.			Latrine for Women.			Covered Passage.			Grand Total.	
					For one.	For two.	Cost.	For one.	For six.	Cost.	For one.	For two.	Cost.	For one.	For four.	Cost.	For one.	For four.	Cost.	Quantity.	Cost.
							RS.			RS.			RS.			RS.			RS.		RS.
Brought forward, ...							1,812			4,559			516			1,129			1,479		9,495
11. *Single Tiled Roof.*																					
i. Woodwork, ...	4	0	0	c. ft.	25	50	200	20	120	480	...	...	...	...	...	...	179	716	2,864	886	3,544
ii. Ironwork, ...	18	0	0	80 lbs.	59	118	27	47	282	63	...	...	...	...	...	...	668	2,672	601	3,072	691
iii. Tiling, ...	10	0	0	100 s. ft.	190	380	33	162	972	97	...	...	...	...	...	...	1,575	6,300	630	7,652	765
																				7,652	5,000
Average rate of Single Tiled Roof,	65	5	6																		
12. *Double Tiled Roof.*																					
i. Woodwork, ...	4	0	0	c. ft.	...	...	...	...	...	...	10	20	80	10	40	160	...	...	...	60	240
ii. Ironwork, ...	18	0	0	80 lbs.	...	...	...	...	...	...	8	16	4	8	32	6	...	...	...	48	10
iii. Tiling,...	19	0	0	100 s. ft.	...	...	...	...	...	...	130	260	49	130	520	99	...	...	...	780	148
																				780	398
Average rate of Double Tiled Roof,	51	0	5																		
13. *Woodwork*, not included under other sub-heads, ..	4	0	0	c. ft.	9,321	18	72	9	54	216	5	10	40	5	20	80	...	...	...	102	408
14. *Ironwork*, not included under other sub-heads, ...	18	0	0	80 lbs.	321	642	144	257	1,542	347	8	16	3	8	32	7	...	...	...	2,232	501
15. *Doors and Windows.*																					
i. Doors,...	1	6	0	s. ft.	51	42	58	21	126	173	...	...	...	...	...	...	...	...	...	168	231
ii. Windows, ...	1	2	0	"	58	116	131	58	348	391	...	...	...	...	...	...	...	...	...	464	522
iii. Fastenings for i and ii, ...	2	0	0	each set.	3	6	12	3	18	36	...	...	...	...	...	...	...	...	...	24	48
																				632	801
Average rate of Doors and Windows, ...	1	4	3	s. ft.																	

(Docketing on back of previous Specimen).

MILITARY WORKS SERVICES.

II. ALLAHABAD DISTRICT.

Abstract of Estimate No. of 188 -8 , for Constructing Quarters for Butcher Sergeant at Allahabad.

For Rupees 5,238.

(Docketing on back of previous Specimen).

MILITARY WORKS SERVICES.

AGRA DISTRICT.

Abstract of Estimate No. of 188 -8 , of the probable cost of Constructing Subsidiary Buildings for Family Quarters at Agra, for 4 blocks, Class II., to accommodate 34 families.

For Rs. 18,137.

5. Stone Slab set in mortar.				s. ft.																	
i. 2" Stone, ...	14	0	0	100	38	76	11	38	228	32	56	112	16	64	256	36	...	...	...	672	95
ii. 1½" "	12	0	0	"	36	72	9	36	216	26	25	50	6	25	100	12	...	...	...	438	53
Average rate for Stone Slab set in mortar, ...	13	6	0	"																1,110	148
6. Flagged Floor.																					
i. Concrete, ...	12	0	0	100 c. ft.	39	78	10	31	186	22	...	...	...	...	...	...	...	...	...	264	32
ii. Flagging, ...	12	0	0	100 s. ft.	119	238	29	93	558	67	...	...	...	...	...	...	...	...	...	796	96
Average rate for Flagged Floor,	16	1	0	"																796	128
7. Lime Plaster and Whitewash.																					
i. Lime plaster, ...	3	0	0	"	729	1,458	44	583	3,498	105	55	110	3	53	220	7	...	...	...	5,286	159
ii. Whitewash, ...	0	4	0	"	729	1,458	4	583	3,498	9	55	110	1	55	220	1	...	...	...	5,286	15
8. Pointing.	2	8	0	"	1,959	3,918	98	1,567	9,402	235	895	1,790	45	983	3,932	98	351	1,404	35	20,446	511
9. Colour-wash.	0	4	0	"	1,056	2,112	5	845	5,070	13	639	1,278	3	727	2,908	7	...	...	...	11,368	28
10. Terraced Roof.																					
i. Woodwork, ...	4	0	0	c. ft.	16	32	128	13	78	312	...	...	...	...	...	...	...	...	...	110	440
ii. Ironwork, ...	18	0	0	80 lbs.	16	32	7	13	78	18	...	...	...	...	...	...	...	...	...	110	25
iii. Stone flagging, ...	14	0	0	100 s. ft.	149	298	42	119	714	100	...	...	...	...	...	...	...	...	...	1,012	142
iv. Terracing, ...	7	8	0	"	210	420	32	168	1,008	76	...	...	...	...	...	...	...	...	...	1,428	108
Average rate of Terraced Roof,	70	10	5																	1,012	715
Carried over, ...						1,812			4,559			516			1,129			1,479			9,495

(Docketing on back of previous Specimen).

MILITARY WORKS SERVICES.

AGRA DISTRICT.

General Abstract of Estimate No. of 188 -8 , of the probable cost of Constructing Subsidiary Buildings for Family Quarters at Agra, for 4 blocks, Class II.

For Rupees 18,137.

	Rs.	a.	p.	per																	
16. *Painting and Varnishing.*				s. ft.																	
i. Painting, ...	3	0	0	100	550	1,100	33	439	2,634	79	115	230	7	115	460	14	723	2,892	87	7,316	220
ii. Varnishing, ...	2	8	0	"	130	260	7	104	624	16	...	...	...	...	...	...	...	...	...	884	23
iii. Coal-tarring, ...	2	0	0	"	211	422	8	169	1,014	20	9	18	1	9	36	1	158	632	13	2,122	43
17. *Sundries.*																					
i. Consolidating kankar, ...	4	8	0	100 c. ft.	59	118	5	48	288	13	109	218	10	109	436	20	214	856	39	1,916	87
ii. Chokut-bolts, ...	18	0	0	80 lbs.	11	22	5	11	66	15	...	...	...	...	...	...	...	...	...	88	20
iii. Boring holes for ii, ...	0	2	0	each.	6	12	2	6	36	5	...	...	...	...	...	...	...	...	...	48	7
iv. Door-seats to Latrines, ...	1	2	0	s. ft.	...	...	...	...	...	...	40	80	90	40	116	180	...	...	...	240	270
Total, ...							2,554			6,510			800			1,696			5,713		17,273
Add Contingencies, at 5 per cent.,							128			325			40			85			286		864
Grand Total, ...							2,682			6,835			840			1,781			5,999		18,137

Cost of each superficial foot of plinth area covered.

Cook-houses for five families, $\frac{2682}{884} = 3{\cdot}07$, or Rs. 3 0 6½ per s. foot.
" " four " $\frac{6835}{2196} = 3{\cdot}11$, " 3 1 9½ "
Latrines for men, ... $\frac{840}{204} = 4{\cdot}11$, " 4 1 9⅓ "
" " women, ... $\frac{1781}{408} = 4{\cdot}36$, " 4 5 10 "
Covered passages, ... $\frac{5999}{3636} = 1{\cdot}65$, " 1 10 5 "

(Specimen).

MILITARY WORKS SERVICES.

AGRA DISTRICT.

General Abstract of Estimate of the probable cost for Constructing Subsidiary Buildings for Family Quarters at Agra, for 4 blocks, Class II.

Names of Buildings.	Plinth area of each building.	Rate per square foot of plinth area.	Cost of each building.	Grand Total Cost.
	Sq. ft.	RS. A. P.	RS.	
Cook-houses for five families, ...	884	3 0 6½	2,682	
" " four " ...	2,196	3 1 9½	6,835	
Latrines for men, ...	204	4 1 9½	840	
" " women, ...	408	4 5 10	1,781	
Covered passages, ...	3,636	1 10 5	5,999	
			Grand Total Cost, ...	18,137

I. The above estimate includes charges for work Establishment, Tools and Plant, &c.

II. The work will be executed by Contract, and will be completed within 9 months.

III. Funds are not allotted in Budget for current year for this work, and an appropriation is solicited to the extent of Rs. 18,137.

IV. Total of Estimate, ... Rs. 18,137
Deduct values of Stock issues, ... " 8,137

Balance cash required, " 10,000

Random-squared coursed rubble,	...	5 to 12 cubic feet.
Random coursed rubble,	... ...	up to 15 „
Dressed ashlar,	... ...	1 to $1\frac{1}{2}$ „
Ashlar in arches,	... ...	1 to $1\frac{1}{2}$ „
Plastering, 1 coat,	... ...	60 s. feet.
„ 2 „	... ...	30 „
„ 3 „	... ...	20 „
Pointing, ...	... ...	100 „
Terraced floors or roofs,	... ...	50 „
Brick-on-edge flooring,	... ...	45 „
Flagged flooring,	... ...	20 „
Allahabad tiling, single,	... ...	35 „
„ „ double,	... ...	15 „
Fixing roof battens,...	... ...	100 „
1 pair batten doors (4′ × 7′),	...	8 days.
Teak-wood framing, &c.,	... ...	1 cubic foot.
1 pair panel doors, ...	... ...	15 days.
1 „ Venetian doors (4′ × 7′),	...	18 „

Load for a two-bullock cart.

Bricks (9″ × $4\frac{1}{2}$″ × $2\frac{3}{4}$″),	... ...	250
Broken stone,	... ...	15 cubic feet.
Gravel, ...	... ...	15 „
Kankar lime,	... ...	13 „
Slaked „ ...	... ...	45 „
Sandstone, ...	... ...	9 „

PART V.

RATES.

RATES.

1. Many circumstances, such as no two workmen executing the same amount of work in the same amount of time, combine to render the preparation of really accurate details of rates a matter of much difficulty, involving the expenditure of considerable time and labour.

2. Under a good contract system where contractors really compete for the execution of a work, the exact accuracy of the rates becomes a matter of secondary importance. For if the rates are too high, the tenders will be proportionately low.

3. The above is, however, probably only true to a limited extent, while at many stations there is little competition among contractors, and work has often to be done by daily labour. It therefore becomes important that rates should be as accurate as time and circumstances will permit.

4. With a view to render some assistance towards attaining this result the information contained in the following pages is given.

5. The tasks a skilled workman can perform may be of assistance where works are being executed by daily labour.

6. The rates in use at the present time at important stations in the different Commands are given for the more common kinds of work, as they may sometimes be useful for comparison.

7. Details of work for several items in constant use are also given, as a guide and check when drawing up similar details for the same kinds of work at other stations.

Task for an experienced Artizan per diem.

Brickwork, ...	15	cubic feet.
Flat archwork, ...	8	,,
Circular ,, ...	7	,,
Honey-comb work, ...	25	,,
Coursed rubble masonry, ...	5 to 10	,,

DETAILS OF COST OF WORK.

DIVISION—*Lucknow.* STATION—*Lucknow.*

Name of Work—*Cut stone finely dressed in verandah pillars and door frames.*

Details of Labour and Materials per cubic foot.		No. or quantity.	Rate.		Amount.			Total.			Grand Total.		
			Cost.	Per	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.
Labour.													
Mason, ..	No.	$\frac{8}{6\frac{1}{2}}$	-/6/-	each.	0	8	9						
" ..	"	¼	-/6/-	"	0	1	6						
" ..	"	⅛	-/6/-	"	0	0	9						
Beldar, ..	"	¼	-/3/-	"	0	0	9	0	11	9			
Materials.													
Rough stone in blocks at quarry station, ..	c. ft.	1	-/8/-	c. ft.	0	8	0						
Railway freight, ..	"	1	-/6/9	"	0	6	9						
Unloading at station and cartage, say 2 miles, ..	"	1	-/1/-	"	0	1	0						
Sundries, ..					0	1	6	1	1	3			
Total Labour and Materials, ..	..	..	..	..	..	..	..	..	..	..	1	13	0

DETAILS OF COST OF WORK.

DIVISION—*Agra.* STATION—*Agra.*

Name of Work—$1\frac{1}{2}''$ *Flagged Flooring on 3″ Concrete.*

Details of Labour and Materials per 100 superficial feet.		No. or quantity.	Rate. Cost.	Rate. Per	Amount. Rs.	A.	P.	Total. Rs.	A.	P.	Grand Total. Rs.	A.	P.
Labour.													
i. *Concrete—*													
Beldars, ..	No.	3	-/2/6	each.	0	7	6						
Coolies, ..	"	2	-/1/6	"	0	3	0						
Bhisties, ..	"	$1\frac{1}{2}$	-/3/-	"	0	4	6						
Grinding mortar, ..	c. ft.	$11\frac{1}{2}$	1/14/-	%	0	3	6	1	2	6			
Materials.													
For Ballast—													
Clean washed kankar, ..	"	28	5/8/-	"	1	8	6						
" bujree, ..	"	10	11/-/-	"	1	1	6						
For Mortar—													
Ground and sifted kankar lime, ..	"	$4\frac{1}{2}$	24/-/-	"	1	1	3						
Clean washed bujree, ..	"	7	11/-/-	"	0	12	3	4	7	6			
Total Labour and Materials, ..	..	..	..	..	..	..	..	..	..	..	5	10	0
Labour.													
ii. $1\frac{1}{2}''$ *Flagged Flooring—*													
Stone masons, ..	No.	5	-/5/-	each.	1	9	0						
Beldars, ..	"	3	-/2/6	"	0	7	6						
Coolies, ..	"	2	-/1/6	"	0	3	0						
Bhisties, ..	"	1	-/3/-	"	0	3	0						
Grinding mortar, ..	c. ft.	15	1/14/-	%	0	4	6	2	11	0			
Materials.													
Stone slabs, ..	s. ft.	110	9/-/-	"	9	14	3						
Kankar lime, ..	c. ft.	6	24/-/-	"	1	7	0						
Washed bujree, ..	"	9	11/-/-	"	0	15	10	12	5	1			
Total Labour and Materials, ..	..	..	..	..	..	..	..	..	..	..	15	0	0
Total for $1\frac{1}{2}''$ Flagged Flooring on 3″ Concrete, ..	..	..	..	..	..	..	..	..	..	..	20	10	0

DETAILS OF COST OF WORK.

DIVISION—*Rawalpindi.* STATION—*Rawalpindi.*

Name of Work—*Flooring laid with Machine Pressed Tiles* 9″ × 9″ × 2″.

Detail of Labour and Materials per 100 superficial feet.		No. or quantity.	RATE.		Amount.			Total.			Grand Total.		
			Cost.	Per	Rs.	A.	P.	Rs.	A.	P.	Rs.	A.	P.
Labour.													
Mason, ..	No.	1	-/12/-	each	0	12	0						
" ..	"	1	-/10/-	"	0	10	0						
Coolies, ..	"	2	-/4/-	"	0	8	0						
Mistri, ..	"	¼	1/-/-	"	0	4	0						
Bhistie, ..	"	1	-/5/-	"	0	5	0	2	7	0			
Materials.													
Tiles, ..	"	187	20/-/-	‰	3	11	10						
Carriage of Tiles, ..	"	187	3/-/-	‰	0	9	0						
Mortar, ..	c. ft.	6	-/4/-	c. ft.	1	8	0						
Carriage of mortar, ..	"	6	..	..	0	2	0	5	14	10			
Contractor's profit, ..	..	..	..	..	..	..	..	0	10	2			
Total Labour and Materials, ..	..	..	..	..	..			..	..	..	9	0	0

DETAILS OF COST OF WORK.

DIVISION—*Bareilly*. STATION—*Bareilly*.

Name of Work—*Lime Plaster with Pure Kankar Lime on Brickwork.*

Details of Labour and Materials per 100 superficial feet.	No. or quantity.		Rate. Cost.	Per	Amount. Rs.	A.	P.	Total. Rs.	A.	P.	Grand Total. Rs.	A.	P.
Labour.													
Masons, ..	No.	1½	-|5|-	each.	0	7	6						
Coolies, ..	"	4	-|1|6	"	0	6	0						
Bhisties, ..	"	½	-|2|6	"	0	1	3						
Beldars, ..	"	½	-|2|6	"	0	1	3						
Mixing—Bullocks, ..	"	¼	-|4|-	"	0	1	0	1	1	0			
Materials.													
Kankar lime, ..	c. ft.	6	28|-|-	%	1	10	10						
Sundries, ..	..		..	..	0	0	2	1	11	0			
Total Labour and Materials, ..	..		..	..	..	..	..	..	..	..			

DETAILS OF COST OF WORK.

DIVISION—*Bareilly*. STATION—*Bareilly*.

Name of Work—*Sheet Iron Roofing, Naini Tal system (improved patern without any exposed screws).*

Details of Labour and Materials per 100 superficial feet.		No. or quantity.	Rate. Cost.	Rate. Per	Amount. Rs.	A.	P.	Total. Rs.	A.	P.	Grand Total. Rs.	A	P.
Labour.													
Carpenters, ..	No.	$3\frac{1}{2}$	-/8/-	each.	1	12	0						
Blacksmiths, ..	"	1	-/8/-	"	0	8	0						
Painters, ..	"	2	-/3/-	"	0	6	0						
Coolies, ..	"	3	-/2/8	"	0	8	0	3	2	0			
Materials.													
Iron sheets (6′ × 2′) (22 B.W.G.), ..	"	$11\frac{1}{8}$	1/10	each.	18	3	0						
Iron sheets (6′ × 2′) (18 B.W.G.), ..	"	$1\frac{1}{3}$	2/8	"	3	6	0						
Fir planking, 1″ including nails and screws.	s. ft	100	6/6	°/o	6	6	0						
Iron clips, catches, rivets, &c., ...	seers	6	-/7/-	seer.	2	10	0						
Olphert's metallic paint,	lbs.	$2\frac{1}{2}$	-/2/-	lbs.	0	5	0						
Linseed oil, ..	"	$2\frac{1}{4}$	-/6/-	"	0	13	6						
Coal-tar, ...	"	$1\frac{1}{4}$	..	"	0	2	6	31	14	0			
Total Labour and Materials, ..	..	..	..	..	..	..	..	..	..	..	35	0	0

DETAILS OF COST OF WORK.

STATION—*Chakrata.*

DIVISION—*Chakrata.*

Name of Work—$1\frac{1}{2}''$ *Deodar flooring including joists.*

Details of Labour and Materials per 100 superficial feet.		No. or quantity.	Rate. Cost.	Rate. Per	Amount. Rs.	A.	P.	Total. Rs.	A.	P.	Grand Total. Rs.	A.	P.
Labour.													
Carpenters, ..	No.	8	-/8/-	each.	4	0	0						
Coolies, ..	"	8	-/4/-	"	2	0	0	6	0	0			
Materials.													
Joists 5 × 10′ × 5″ × 6″	c. ft.	$8\frac{1}{3}$	1/12/-	c. ft.	14	9	4						
$1\frac{1}{2}''$ Planks 110 s. ft., ..	"	$13\frac{3}{4}$	1/8/-	"	20	10	1						
4″ Nails, ..	cwt.	$\frac{1}{7}$	17/8/-	cwt.	2	8	0						
Coal-tar, ..	"	$\frac{1}{8}$	11/-/-	"	1	6	0	39	1	5			
Total Labour and Materials, ..	..	..	..	..	..	..	..	..	..	..	45		

DETAILS OF COST OF WORK.

DIVISION—*Bareilly.* STATION—*Bareilly.*

Name of Work—*Sheet Iron Roofing, Naini Tal system (improved patern without any exposed screws).*

Details of Labour and Materials per 100 superficial feet.		No. or quantity.	Rate. Cost.	Rate. Per	Amount. Rs.	A.	P.	Total. Rs.	A.	P.	Grand Total. Rs.	A	P.
Labour.													
Carpenters, ..	No.	$3\frac{1}{2}$	-/8/-	each.	1	12	0						
Blacksmiths, ..	"	1	-/8/-	"	0	8	0						
Painters, ..	"	2	-/3/-	"	0	6	0						
Coolies, ..	"	3	-/2/8	"	0	8	0	3	2	0			
Materials.													
Iron sheets (6' × 2') (22 B.W.G.), ..	"	$11\frac{1}{8}$	1/10	each.	18	3	0						
Iron sheets (6' × 2') (18 B.W.G.), ..	"	$1\frac{1}{8}$	2/8	"	3	6	0						
Fir planking, 1" including nails and screws,	s. ft	100	6/6	%	6	6	0						
Iron clips, catches, rivets, &c., ...	seers	6	-/7/-	seer.	2	10	0						
Olphert's metallic paint,	lbs.	$2\frac{1}{2}$	-/2/-	lbs.	0	5	0						
Linseed oil, ..	"	$2\frac{1}{4}$	-/6/-	"	0	13	6						
Coal-tar, ...	"	$1\frac{1}{4}$	..	"	0	2	6	31	14	0			
Total Labour and Materials, ..	..	..	..	..	..	..	..	..	..	..	35	0	0

DETAILS OF COST OF WORK.

DIVISION—*Lucknow.* STATION—*Lucknow.*

Name of Work—*Ironwork, Straps, Bolts, &c., &c.*

Detail of Labour and Materials per cwt.		No. or quantity.	Rate. Cost.	Rate. Per	Amount. Rs.	A.	P.	Total. Rs.	A.	P.	Grand Total. Rs.	A.	P.
Labour.													
Smith, ..	No.	1	-/8/-	day.	0		0						
" ..	"	23	-/6/-	"	8	10	0						
" ..	"	6	-/2/6	"	0	15	0						
Beldars, ..	"	18	-/2/6	"	2	13	0						
" ..	"	6	-/2/3	"	0	13	6	13	11	6			
Materials.													
Iron rods ⅝″, ..	cwt.	qr. 0-3-0	7/8/-	cwt.									
" ½″, ..	"	qr. lbs. 0-1-14			16	14	0						
Iron flat, 1 3/16″ × ⅜″, ..	"	1-0-14											
Iron nuts, ½″ × ⅝″, ..	"	12	-/4/-	lb.	3	0	0						
Coals, ..	md.	3	-/7/-	md.	1	5	0	21	3	0			
Grand Total, ..	..	..	..	..	..	..	..	..	..	..	34	14	6
Rs. 34-14-6 ÷ 2 cwt. 1 qr. 4 lbs. = per cwt. ..	..	..	..	..	..	..	..	..	..	..	15	4	4
Cost of fixing, &c., ..	..	..	..	..	..	..	..	..	..	..	2	0	0
Total, ..	..	..	..	..	..	..	..	..	..	..	17	4	4
Say, ..	..	..	..	..	..	..	..	..	..	..	17	8	0

STATEMENT SHOWING THE RATES FOR VARIOUS KINDS OF WORK IN THE COMMANDS,

Sub-heads.	Per	PUNJAB.						
		Rawalpindi.	Murree.	Meean Meer.	Umballa.	Kasauli.	Meerut.	Naini Tal.
Stone Masonry.								
Ashlar work, ...	c. ft.	1/-/-	1/-/-	...	...	...	...	...
Coursed rubble in lime, ...	°/o c. ft.	50/-/-	25/-/-	...	...	29/8/-	...	17/-/-
" " in clay, ...	"	...	...	...	...	18/4/-	...	10/-/-
Cut stones, bed-plates, and corbels with holes bored, ...	c. ft.	2/-/-	...	...	...	1/6/-	2/-/-	...
Dry rubble masonry, rough,... ...	°/o c. ft.	7/-/- to 16/-/-	12/-/-	...	...	16/12/-	...	...
" in breast and retaining walls dressed on one face, ...	"	9/-/-	9/-/-	...	...	6/8/-	...	4/-/-
Sunshade, Agra stone, ...	each.	18/-/-	...	...	...	...	...	...
Flooring.								
Asphalte flooring, 1″ thick,... ...	°/o s. ft.	30/-/-	31/-/-	32/-/-	...	...	...	...
Brick, flat, exclusive of concrete, ...	"	9/-/-	...	7/-/-	7/8/-	...	...	...
Brick-on-edge, ... "	"	12/8/-	...	...	13/-/-	...	12/8/-	...
Clay floors in stables and latrines, including removal outside Cantonments, and bringing fresh earth from outside Cantonments, ...	°/o c. ft.	2/-/-	2/8/-	1/8/-	2/2/-	...	...	...
Flagged flooring, 1½″, exclusive of concrete, ...	°/o s. ft.	40/-/-	...	24/6/-	30/-/-	35/-/-	25/-8/-	40/-/-
Indian stone Patent floor, 1″ thick, ...	"	50/-/-	...	...	...	...	...	...
Terraced flooring, 3″ thick, ...	"	6/-/-	6/-/-	...	...	...	...	...
" " 4″ " ...	"	7/8/-	7/8/-	...	...	...	...	...
" " 5″ " ...	"	...	...	...	...	...	...	...
" " 6″ " ...	"	12/-/-	12/-/-	10/-/-	...	...	...	...
Plaster and Pointing.								
Leeping, cow-dung, fine, ...	"	-/1/-	-/2/-	-/1/-	-/1/-	-/1/-	...	...
Plaster, lime mortar, on brick walls, new,	"	2/8/-	3/-/-	2/4/-	2/4/-	4/8/-	3/-/-	4/-/-
" " " on stone walls, ...	"	4/-/-	4/-/-	...	...	...	...	...
" Portland Cement, ¼″ thick, ...	"	7/-/-	9/-/-	4/-/-	6/-/-	...	...	...
" mud, on brick walls, inclusive of leeping, ...	"	-/8/-	-/9/-	-/6/-	-/5/-	-/10/-	-/6/-	1/-/-
Plaster, mud, on stone walls, inclusive of leeping, ...	"	-/10/-	1/-/-	...	...	...	...	...
Lime or flush pointing on new walls,...	"	2/8/-	2/8/-	2/-/-	1/4/-	...	1/12/-	... 2/-/-
" " on brick in clay walls, ...	"	2/2/-	...	...	...	...		...
Lime or flush pointing on thick or old walls, ...	"	3/-/-	3/-/-	...	...	2/12/-	...	...
Cement pointing on brick walls, ...	"	5/-/-	5/-/-	2/8/-	...	...	...	...
Scraping walls, ...	"	-/1/-	...	-/1/6	-/1/-	-/1/-	...	...
White and Color-washing.								
Color-washing, 1 coat of whitewash and 2 coats of color-wash,.. ...	"	-/4/-	-/6/-	...	...	...	...	...
Whitewashing, 3 coats on scraped walls,	"	-/4/-	-/4/-	-/3/6	-/4/-	-/5/-	-/3/6	-/4/-
Whitewashing, 1 coat on old walls, ...	"	-/1/6	-/2/-	-/1/6	-/1/8	-/2/-	...	...

STATEMENT SHOWING THE RATES FOR VARIOUS KINDS OF WORK IN THE COMMANDS,

Item Number.	Sub-heads.	Per	PUNJAB. Rawalpindi.	Murree.	Meean Meer.	Umballa.	Kasauli.	Meerut.	Naini Tal.
	Wood work, Carpentry and Joinery.								
53	Teak in framing beams, &c., ..	c. ft.	..	..	4/-/-	..	..	4/8/-	5/-/-
54	Sál " " ..	"	..	..	..	3/8/-	..	4/4/-	3/4/-
55	Chír " " ..	"	..	..	..	2/-/-	1/6/-	..	1/4/-
56	Deodar " " ..	"	2/2/-	..	1/14/-	2/4/-	2/-/-	3/4/-	..
57	Teak doors and windows, framed and glazed, ...	"	..	..	..	..	..	1/2/-	1/-/-
58	Teak doors and windows, grooved and beaded and battened, ...	"	..	..	..	..	..	1/2/-	1/6/-
59	Deodar doors and windows, framed and glazed, ...	s. ft.	1/4/-	..	-/14/-	-/14/-	-/14/6	..	..
60	Deodar doors and windows, grooved, beaded and battened, ...	"	-/12/-	..	-/8/-	-/13/-	-/14/-	-/12/-	..
61	Curbs for well-sinking, kikur, ..	c. ft.	3/12/-	..	..	..	..	..	..
62	Boarded floor, plain, 1½", tongued and grooved, and screwed down, ..	s. ft.	28/-/- °/o	..	35/-/- °/o	..	27/8/- °/o	..	..
	Ironwork.								
63	Ordinary ironwork or mild steel for trusses, bolts, straps, &c., ..	cwt.	20/8/-	24/8/-	19/-/-	14/-/-	17/8/-	21/-/-	20/-/-
64	Fine ironwork or mild steel for small house fittings, ...	"	..	..	..	..	..	25/-/-	22/-/-
65	Cast ironwork, ...	"	16/4/-	22/-/-	..	..	13/-/-	..	..
	Brass-work.								
66	Brass-work, filed and fixed, ..	seer.	1/8/-	2/8/-	..	..	..	..	..
67	Copper " " "	"	2/-/-	2/8/-	..	..	..	..	..
	Painting and Glazing.								
68	Painting, 1 coat, country or Olpherts, ..	°/o s. ft.	1/4/-	1/-/-	-/9/-	-/11/-	-/11/6	..	..
69	" 2 " " " ..	"	2/-/-	2/-/-	1/-/-	1/3/-	1/4/-	..	..
70	" 1 " priming, and 2 coats finishing, ...	"	3/-/-	3/-/-	..	..	..	..	..
71	Painting, 1 coat, Europe, ...	"	1/6/-	1/8/-	1/-/-	1/-/-	1/2/-	..	..
72	" 2 " "	"	2/8/-	3/-/-	1/11/-	1/12/-	1/14/-	..	..
73	" 1 " priming, and 2 coats finishing, ...	"	3/8/-	4/8/-	2/6/-	..	..	2/8/-	2/8/-
74	Varnishing, 1 coat, ...	"	1/-/-	1/4/-	-/10/-	-/14/-	-/14/-	-/14/-	..
75	" 2 "	"	1/12/-	2/-/-	1/8/-	1/8/-	1/12/-	1/8/-	2/8/-
76	Coal-tarring, 1 coat, ...	"	1/-/-	1/4/-	-/10/-	-/8/-	-/9/6	..	..
77	" 2 "	"	1/12/-	2/-/-	1/-/-	-/14/-	1/-/-	..	..
78	Letters and figures, ...	inch.	-/-/6	-/-/6	-/-/6	..	..	..	..
79	Pane of glass, 8" × 10", ...	each.	-/4/-	-/3/3	-/3/-	-/3/-	-/3/6	..	..
80	" " 10" × 12", ...	"	-/5/-	-/5/-	-/3/-	-/4/6	-/4/6	..	..

STATEMENT SHOWING THE RATES FOR VARIOUS KINDS OF WORK IN THE COMMANDS,

Item Number.	Sub-head.	Per	Punjab.						
			Rawalpindi.	Murree.	Meean Meer.	Umballa.	Kasauli.	Meerut.	Naini Tal.
	Roof Covering.								
81	Double Allahabad tiling, 1st class, ...	°/o s. ft	19/-/-	...	34/-/-	21/8/-	...	17/8/-	...
82	Single " " " ...	"	10/-/-	...	17/-/-	11/-/-	...	9/8/-	...
83	Country tiling roof (double), ...	"	...	...	...	...	...	...	...
84	Mangalore tiling, ...	"	...	...	...	...	...	...	...
85	Galvanized corrugated sheet-iron roof, 20 B. W. G., ...	"	32/8/-	34/3/-	...	34/-/-	38/-/-	...	...
86	Galvanized plain sheet-iron roof, 22 B. W. G., without planking, laid Naini Tal system, ...	"	26/8/-	30/12/-	30/-/-	...	...	...	...
87	Mud and mat roof, ...	"	4/8/-	...	4/8/-	...	...	...	..
88	Mud roofing 6″ on tiles, 12″ × 6″ × 2″,	"	9/-/-	...	10/-/-	...	...	...	...
89	Plain sheet-iron roof, Naini Tal pattern, including planks, painting, &c., 22 B. W. G., ...	"	36/-/-	34/-/-	...	...	...	...	...
90	Terraced roofing of 12″ × 6″ × 2″ tiles with 5″ of fine concrete, and pointed underside, ...	"	19/-/-	...	16/-/-	16/4/-	...	...	...
	Ceiling.								
91	Pine wood ½″ ceiling, rebated, beaded, battened, and dowelled, ...	"	...	...	...	18/8/- (¾″) Deodar	19/-/- (¾″) Deodar	16/-/-	...
92	Cloth ceiling, including frames complete, ...	"	10/8/-	...	5/12/-	5/12/-	5/14/-	7/-/-	6/-/-
93	Lathe and plaster ceiling, ...	"	8/-/-	9/-/-	...	...	...	...	...
	Road Metalling.								
94	Collection of kankar for road-making,	°/o c. ft.	...	...	6/-/-	14/8/-	...	7/4/-	...
95	Collection of stone metal for road making, ...	"	9/-/-	2/8/-	...	14/8/-	...	...	...
96	Consolidation of kankar, ...	"	...	...	1/4/-	1/8/-		1/-/-	...
97	Consolidation of stone metal, ...	"	2/-/- (S.P.)	4/8/- (B.P.)	...	1/12/- (B.P.)	...	...	...
	Miscellaneous.								
98	Drilling holes in brick in lime wall, ...	r. ft.	-/8/-	...	...	...	...	...	...
99	" " ., stones for bolts, &c.,...	"	1/-/-	...	...	...	...	...	...
100	Punkahs, Mortimer, lowering bars, repairing and preparing for pulling and raising bars and tying them neatly to the frames, ...	each.	-/3/-	...	...	...	...	...	...
101	Sweeping chimneys, ...	"	-/1/-	-/1/-	-/1/-	-/1/6	-/1/6	...	...

PRINCIPAL STATIONS IN THE PUNJAB, BENGAL, MADRAS AND BOMBAY MILITARY WORKS.

Bengal.				Madras.					Bombay.		
Jhansi.	Lucknow.	Fort William.	Darjeeling.	Secunderabad.	Madras.	Bangalore.	Wellington.	Rangoon.	[illegible]	[illegible]	[illegible]

PRINCIPAL STATIONS IN THE PUNJAB, BENGAL, MADRAS AND BOMBAY MILITARY WORKS.

Bengal.				Madras.					Bombay.			
Jhansi.	Lucknow.	Fort William.	Darjeeling.	Secundrabad.	Madras.	Bangalore.	Wellington.	Rangoon.	Quetta.	Poona.	Belgaum.	Aden.
4/8/-	4/-/-	3/-/-	..	4/8/-	3/8/- to 3/12/-	3/8/-	..	3/-/-	4/4/-	..	4/4/-	5/8/-
3/12-	3/8/-	3/4/-	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	3/-/-	..	..	Ben. teak 4/8/- Deal 3/8/-
1/-/-	1/4/-	-/15/-	1/2/-	1/2/-	1/2/-	..	1/12/-	-/14/- to 1/8/-	1/14/-	1/8/-	1/12/-	2/8/-
1/-/-	1/4/-	-/11/-	..	1/2/-	1/4/-	-/12/-	1/4/-	..	2/-/-	1/6/-	1/8/-	2/-/-
..	..	..	..	..	..	..	..	..	-/15/-	..	..	Ben. teak 2/2/-
..	..	..	..	..	..	..	..	..	-/12/-	..	..	Ben. teak 1/12/-
..	..	..	..	..	..	..	..	..	..	..	3/-/-	..
..	-/10/-	..	..	..	-/7/9	..	..	24/-/- to 27/-/-	..	..	-/12/-	Teak 60/- Ben. teak 50/-/-
17/8/-	17/8/-	13/-/-	18/-/-	28/-/-	21/-/-	..	..	-/3/- per lb.	21/-/-	..	17/8/-	21/-/-
21/-/-	17/8/-	14/8/-	19/-/-	30/-/-	25/-/-	..	..	-/4/- per lb.	..	..	28/-/-	28/-/-
..	..	9/-/-	..	14/-/-	12/-/-	..	..	-/8/- to -/12/- per lb.	15/-/-	..	..	10/-/-
..	1/-/-	..	..	..	1/8/-	..	..	..	..	..	..	1/8/-
..	1/4/-	..	..	..	1/12/-	..	..	4/-/- per seer.	..	..	..	2/-/-
..	..	..	..	-/14/-	1/4/-	..	..	..	1/-/-	..	-/6/-	1/8/-
..	..	..	..	1/8/-	..	..	..	..	1/12/-	..	..	..
..	..	..	..	2/8/-	2/10/-	..	..	2/-/-	..	..	2/-/-	4/4/-
..	-/12/-	..	..	1/4/-	1/4/-	..	..	..	1/6/-	..	1/-/-	3/-/-
..	1/8/-	..	..	2/-/-	2/-/-	1/14/-	..	3/8/-	2/6/-	..	2/-/-	4/12/-
2/8/-	2/12/-	..	..	3/-/-	2/10/-	..	3/-/-	2/8/-	..	..	2/8/-	5/12/-
-/14/-	-/10/-	1/2/-	1/6/-	..	1/8/-	..	..	3/8/-	1/4/-	..	-/12/-	2/8/-
2/8/-	1/4/-	2/2/-	2/6/-	..	2/10/-	..	..	-/8/-	2/1/-	..	1/8/-	4/-/-
	Indian.											
..	-/6/-	-/8/-	-/12/-	1/-/-	-/8/-	..	..	-/10/-	-/8/-	..	-/12/-	-/8/-
..	-/12/-	1/-/-	1/8/-	1/8/-	-/12/-	..	..	-/1/-	..	..	1/8/-	-/14/-
..	-/-/6 to -/2/-	-/2/-	-/2/6	..	-/-/6	..	..	each.	-/-/4	..	-/-/4	-/-/3
..	-/4/-	-/2/6	..	..	-/3/6-	..	..	-/6/-	..	..	-/4/-	-/4/6
..	-/4/-	-/3/6	..	..	-/4/-	..	..	-/2/-	..	..	-/5/-	-/2/-

PRINCIPAL STATIONS IN THE PUNJAB, BENGAL, MADRAS AND BOMBAY
MILITARY WORKS.

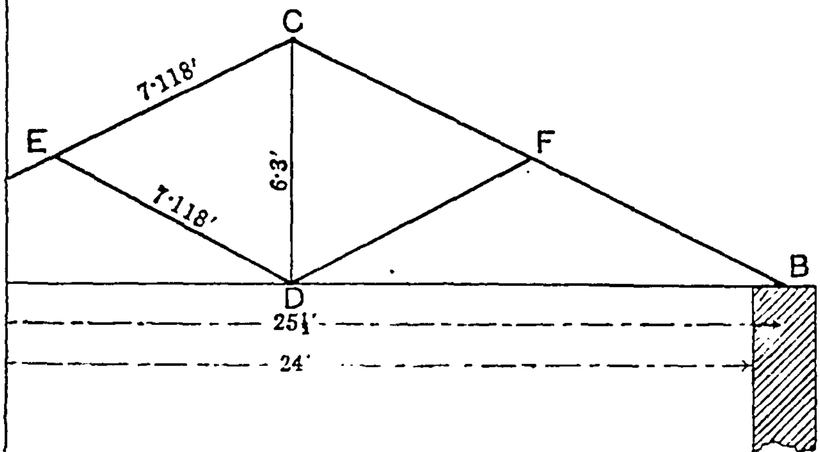
Bengal.				Madras.					Bombay.			
Jhansi.	Lucknow.	Fort William.	Darjeeling.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
25/-/-	16/8/-	...	...	32/-/-	...	...	...	...	...	...	...	...
12/8/-	8/-/-	...	...	18/-/-	...	...	...	...	...	...	...	...
...	...	...	...	20/-/-	14/-/- flat and pan tiles chunam borders with reepers.	...	...	19/-/- Burma tiles.	...	...	18/-/-	...
...	...	22/-/-	...	21/-/-	15/8/-	19/-/-	...	26/-/- with battens	...	...	18/-/-	60/-/-
...	...	30/-/-	40/-/-	32/-/-	33/-/-	...	...	32/-/-	60/-/-	...	90/-/-	66/8/-
...	...	32/-/-	40/-/-	32/-/-	...	...	...	76/-/-	...	88/-/-	...	...
...	...	...	...	...	...	...	...	...	4/8/-	...	...	...
...	...	...	...	...	...	...	...	...	...	...	...	...
...	...	51/-/-	52/-/-	...	26/4/-	...	34/7/-	...	70/-/-	...	...	...

PART VI.

PLATES.

Fig. 1.

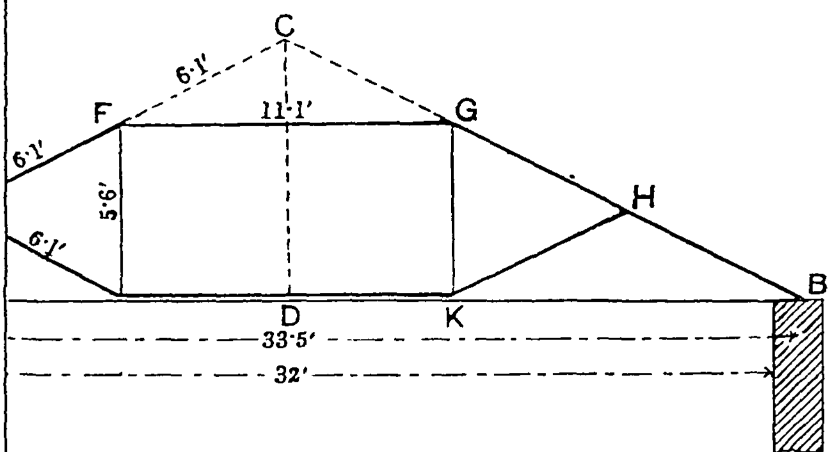
EXAMPLE III.



Scale—6 feet = 1 inch

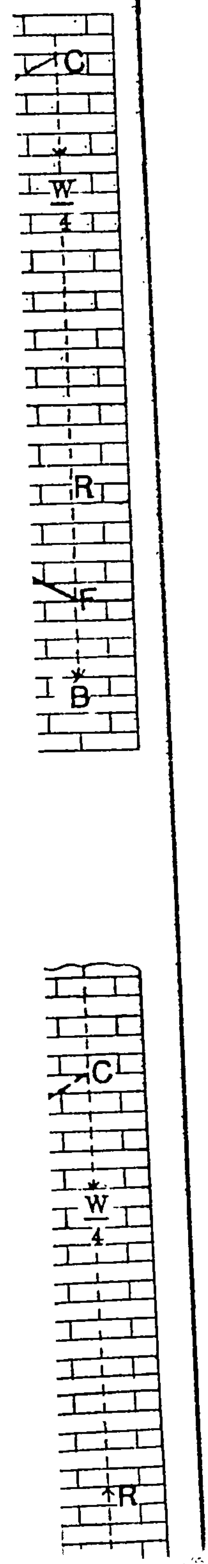
Fig. 2.

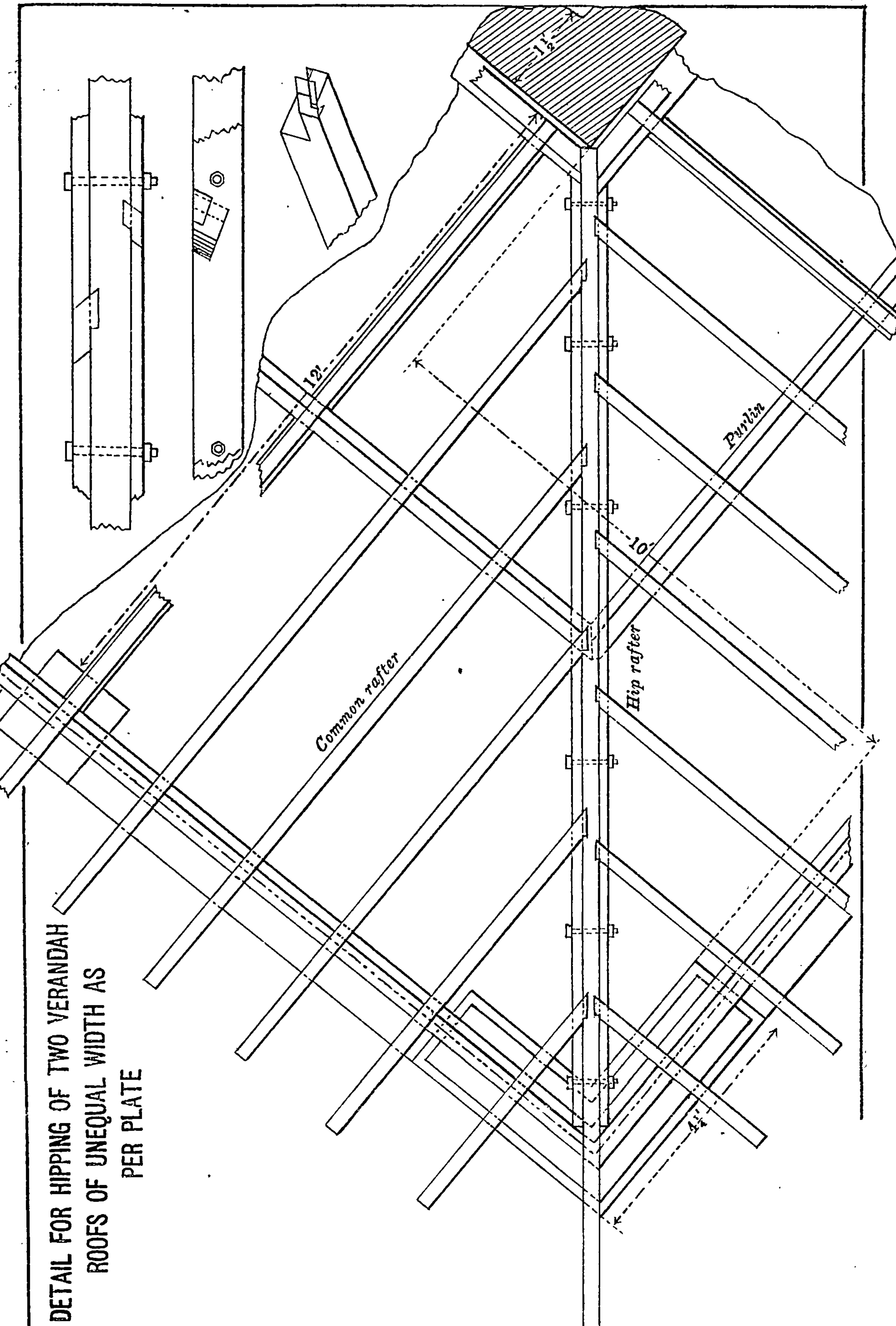
EXAMPLE IV.



Scale—7½ feet = 1 inch

ATE V.





DETAIL FOR HIPPING OF TWO VERANDAH ROOFS OF UNEQUAL WIDTH AS PER PLATE

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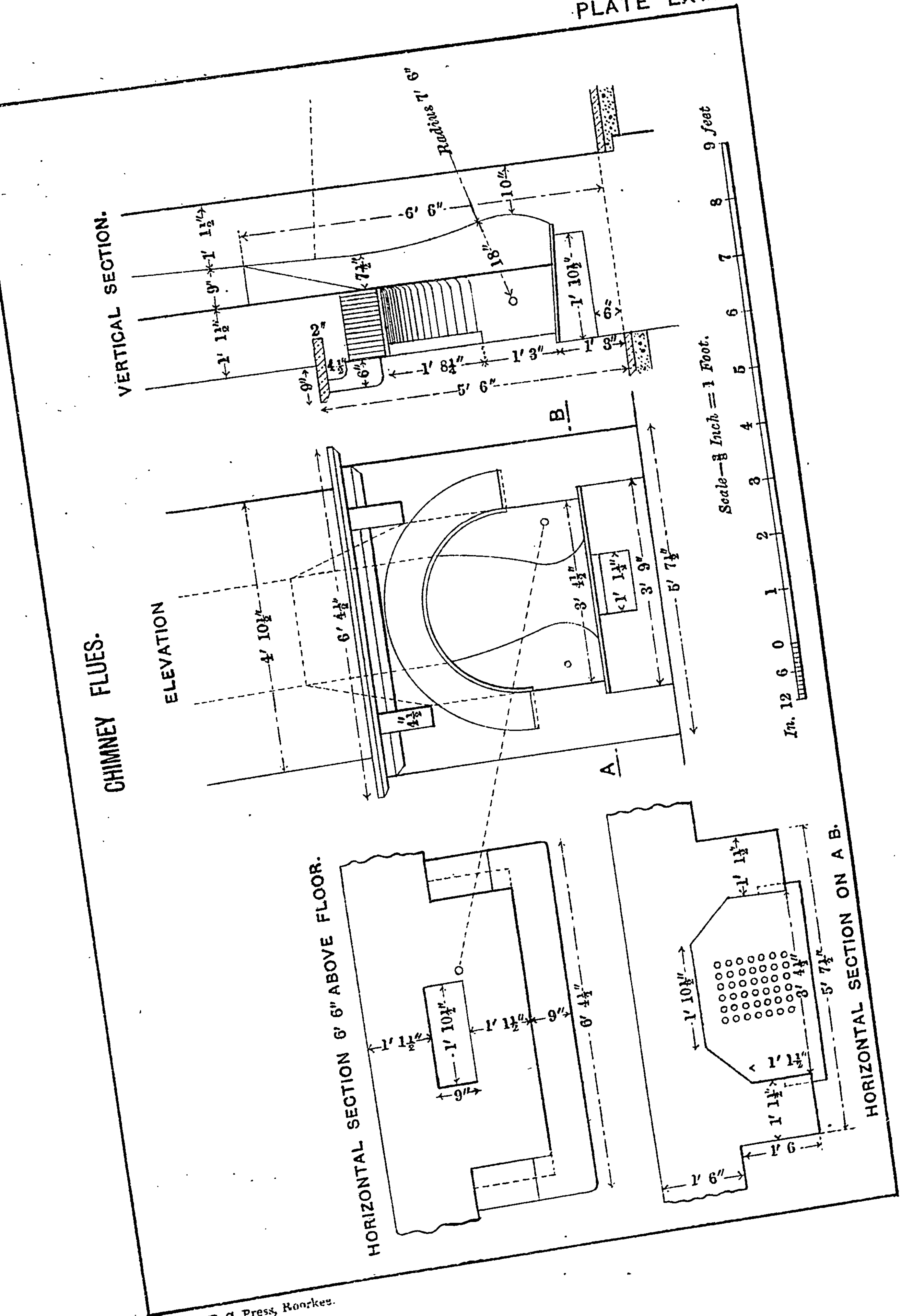
PLATE LXVII



Litho., T. C. Press, Roorkee.

SPECIAL FLAT ALLAHABAD TILES.

Fig. 5.
ELEVATION.

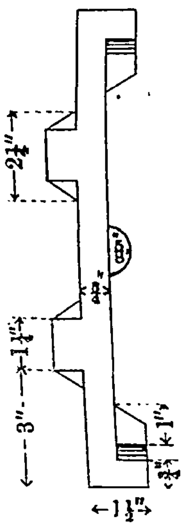
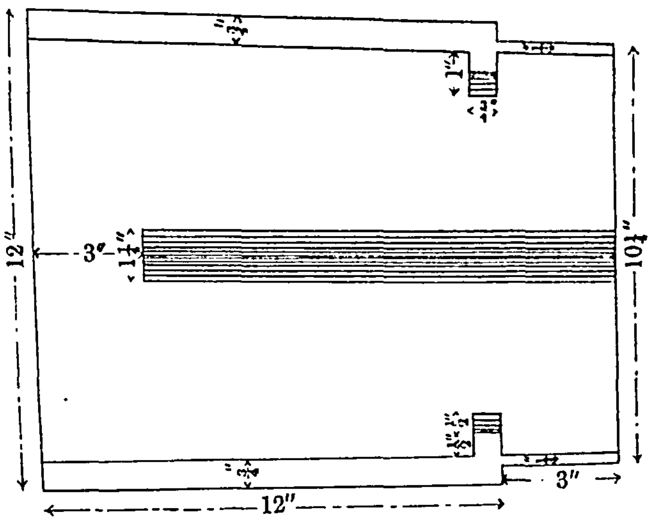


Fig. 4.
PLAN.



STRONG TILE FOR UPPER LAYER.

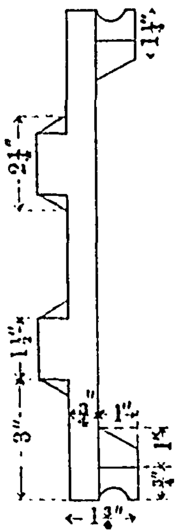
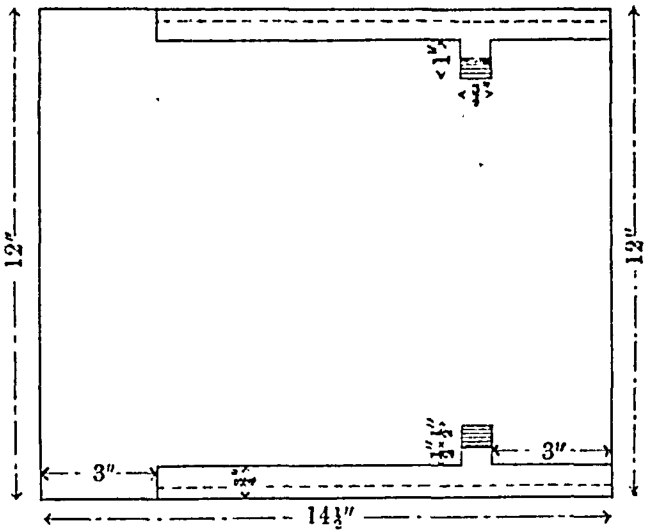


Fig. 2.
ELEVATION.

Fig. 1.
PLAN.



TILE FOR USE IN LOWER LAYER TO KEEP OUT DUST.

Fig. 6.
ISOMETRIC VIEW.

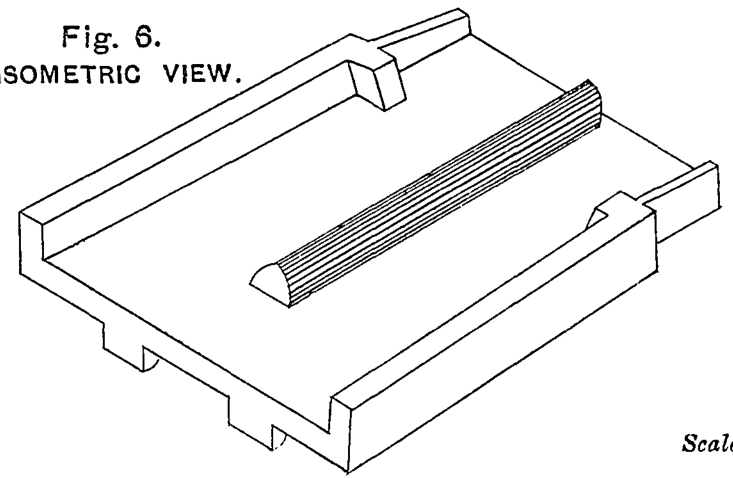
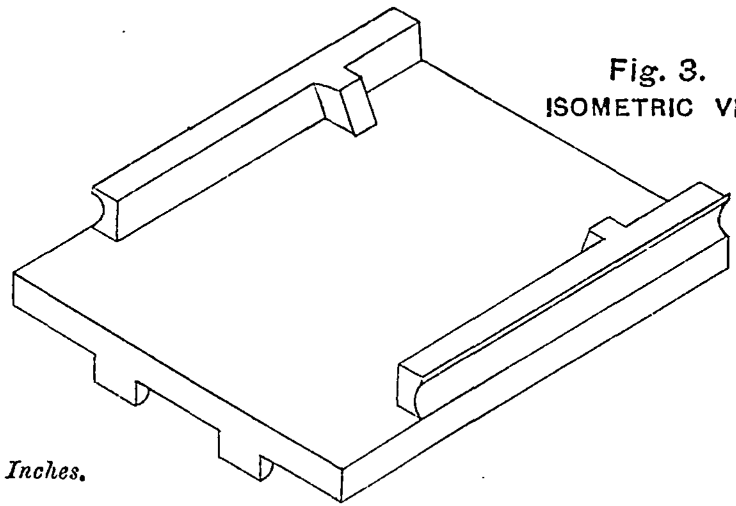


Fig. 3.
ISOMETRIC VIEW.



Scale—1 Foot = 2 Inches.

Litho, T. C. Press, Roorkee.

and by one 2-inch screw driven diagonally through the clip as shown in *Fig.* 4, *Plate* LXXIV. One batten is required for each clip.

The battens will be tarred on the underside before laying.

Page 2. IV. Clips.

Dele he 1st sentence of the note at the end of this paragraph, and *substitute* the following :—

"The junction in figure 4 is at the centre of a sheet ; at the top and bottom the section would show two sheets over the clip and two sheets under, as in figure 3."

terally will be made
of the form shown
nised locally where
ey should be tarred
and battens by two
4.

Fig. 2, the short end
ber of screws will be

covering, one clip is
sides of each sheet ;
8′ × 3′ sheets four

clips should be given on each side, one being placed distant a third of the length of the sheet from each end. The clips at the top and bottom of each sheet should be fixed so that the lower side of the clip is $2\frac{1}{4}$ inches from the lower edge of the overlapping sheet : and in all cases the centre of the clip will be immediately over the centre of the batten.

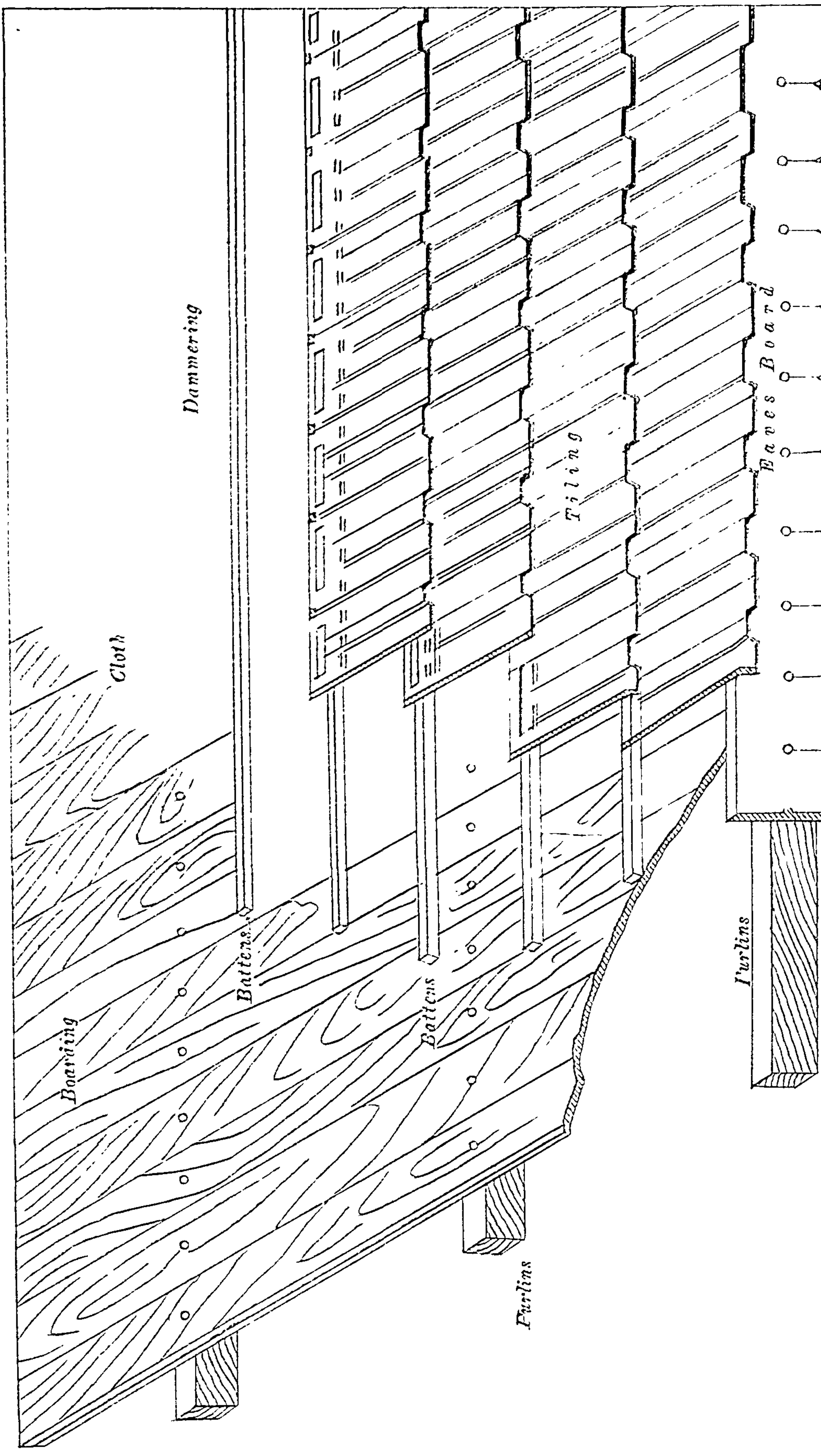
Note.—The junction shown in *Fig.* 3 is at the centre of a sheet ; at the top and bottom the section would show two sheets over the clip and two sheets under. For 6′ × 2′ sheets the total number of clips required is 2 per sheet—for 8′ × 3′ sheets 3 per sheet : to these must be added the extra clips required at the eaves and along one short side of the roof.

V. Hooks.—As in the "Naini Tal" pattern of roofing, hooks are required at the eaves and ridge : these are shown in *Figs.* 5 and 2. They should be made of $1\frac{1}{2}''$ × 14 B. W. G. mild steel, and the portion exposed to view should be galvanised if the roof clips have been so treated.

VI. Method of Laying.—The roof must always be laid so that the exposed ends of the clips are on the leeward side of the battens with reference to the prevailing wind during the rains.

The distance apart having been determined as in para. IV., an overlap in the length of sheets of 6 inches being allowed for, the first line of battens is laid $1\frac{1}{8}$-inch clear of the leeward edge of the roof. Gauges consisting of

MANGALORE TILING OVER PLANKING AND DAMMER.



Battens $12\frac{1}{2}$ inches from centre to centre

Litho., T. C. Press. Roorkee.

the necessary splay on either side being given by driving hard wood wedges of the proper shape under the sheets while still in the press.

The ridge sheets should overlap at least 6 inches longitudinally, and should as a rule be laid on planking as shown in *Fig.* 2. In subsidiary buildings it may be laid direct on the uppermost battens.

LE MESURIER SYSTEM OF ROOFING.

SPECIFICATION.

I. Sheeting.—The roof covering will consist of plain sheet-iron, galvanised or ungalvanised, as may be separately specified, and of the gauge decided on. Ungalvanised iron will be given a coat of tar laid on hot on the underside before being placed in position, and will receive two coats of Olphert's paint after laying is completed.

When no ridge planking is laid and sheets 3 feet broad are used for the roof the ridging should be of 20 B. W. G. sheet iron except in unexposed situations; in other cases 22 B. W. G. sheets may be used for the ridging.

Before laying, the sheets (when not imported in a finished condition) will be bent in a press; after pressing, the two long sides of the sheet will be as in *Fig.* 4 of accompanying drawing, which is drawn half size.

II. Planking.—The sheeting will be laid on planking of the timber separately specified. The planks will be 6 or 7 inches broad and 1 inch thick laid horizontally. In the majority of stations when the span does not exceed 25 feet it will be found most economical to lay this boarding direct on the wooden principal rafters of trusses. The distance apart of these trusses, or of the common rafters where purlins are used, should not exceed 6 feet with local planking of average quality. Before the sheets are laid the planking and battens will be given one coat of tar laid on hot. In subsidiary buildings the sheeting may be laid either on "open boarding" or on purlins as with corrugated iron.

III. Battens.—The battens will be 6 inches long by 1½ inches broad rounded on the top to a semicircle of ¾-inch radius; they should be roughly cut from any scraps of wood which may be available. They will be fastened to the planking by one 1¾-inch screw driven from above,

pieces of hoop iron bent to the exact shape of a prepared sheet, are then placed in the position the sheets will occupy on the boarding—one over the bottom batten and one over the top. A string is then stretched between the points thus determined, and the second row of battens fixed by a single $1\frac{3}{4}$-inch screw driven $1\frac{1}{2}$ inches from the upper end of the batten: this process is repeated throughout the roof, care being taken to get the screws fixing the batten in a straight line. The last line of battens will be laid $1\frac{1}{8}$ inches clear of the windward edge of the roof.

The battens fixed, the first row of clips is laid, one over the centre of each batten on the leeward edge of the roof, and fastened by three screws as in *Fig.* 4. The first line of sheets is then laid over these clips, an overlap of 6 inches being given, and each sheet fastened by a single 1-inch screw placed $1\frac{1}{2}$ inches from its upper edge midway between the battens. The upturned exposed end of the clip is then hammered down with a *wooden* mallet to the position shown in *Fig.* 4.

The first line of sheets having been laid the second line of clips is laid over their outer (windward) edge and screwed down, then the second line of sheets and so on until the whole roof is covered.

The sheets in the last line (on the windward side) have in all cases to be specially bent, as the two long sides must be similar, and usually require to be cut to a special breadth. The sheets should be laid from the eaves upwards: the uppermost sheet being cut to such a length as will ensure the ridging sheet overlapping it by at least 10 inches and its upper edge should be turned up approximately in the form of a semi-circle of $\frac{1}{2}$-inch diameter, the long edges being cut to enable this to be done.

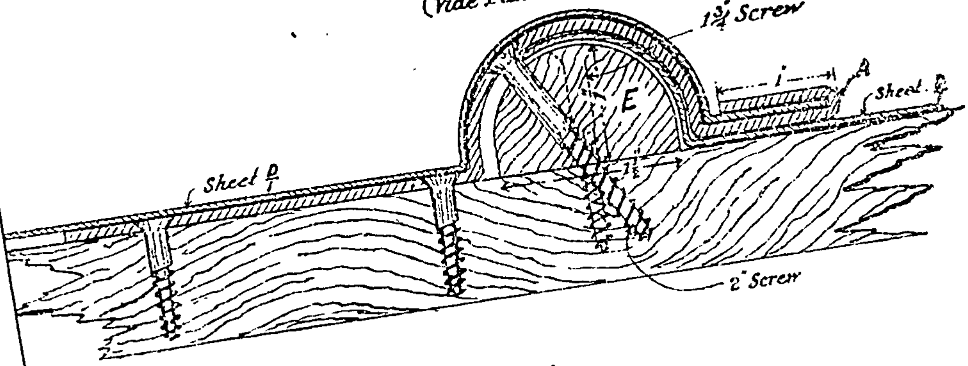
Note.—With inexperienced work-people it is advisable to lay the battens and sheeting simultaneously as the work proceeds, the work on the battens being kept slightly ahead of the laying of the sheets. When the carpenters in charge fully understand the work it will be found best to lay all the battens first. When it is necessary to lay a large roof as quickly as possible two parties should be employed; one fixing the sheets and clips, the other the battens.

VII. Ridging.—The ridging will be laid on the same principle with a special clip as in *Fig.* 2.

The breadth of the ridge sheets will be separately specified, [illegible] usually be 2 feet before pressing.

The ridge sheets may be bent in the same press [illegible]

FIG. 4.
SECTION ON N O.
(Vide Plate LXXV.)



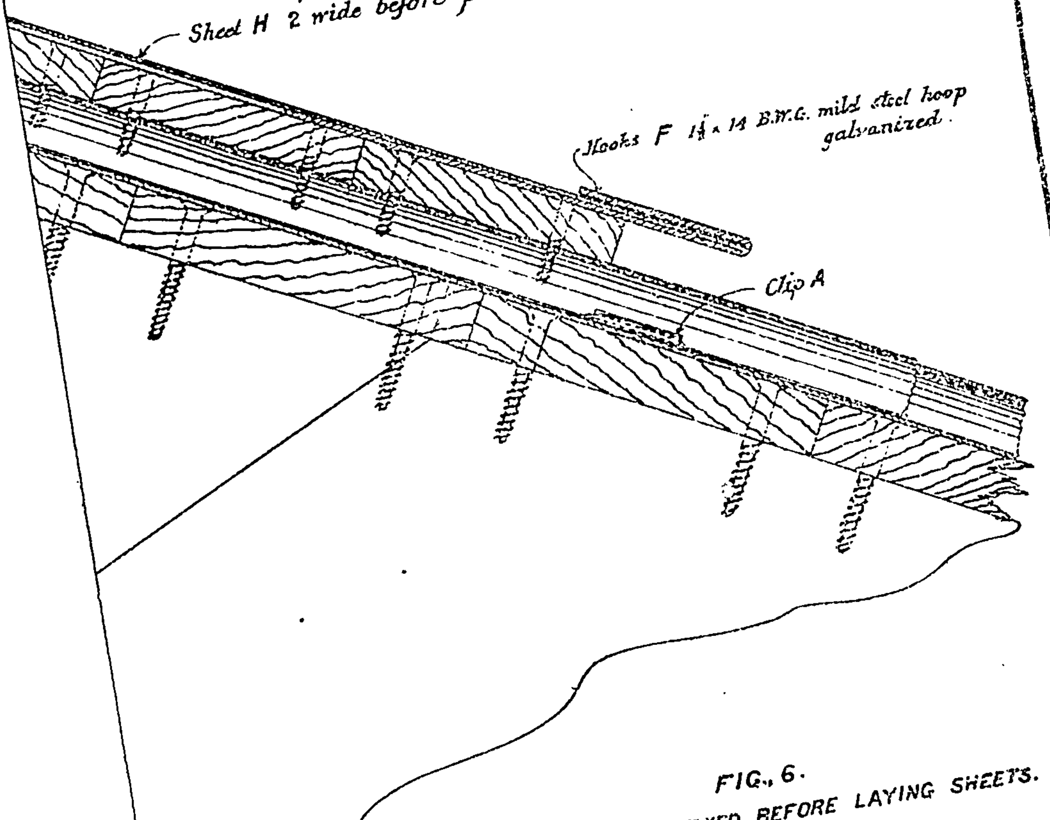
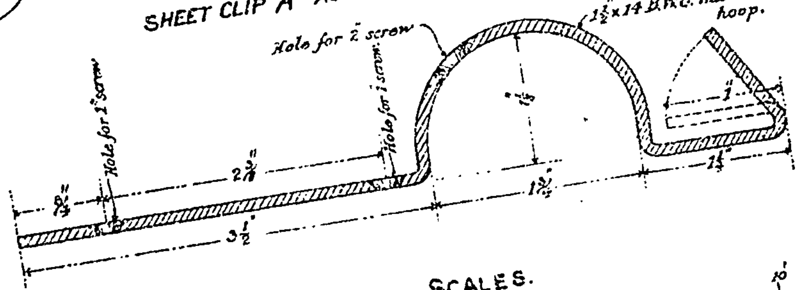
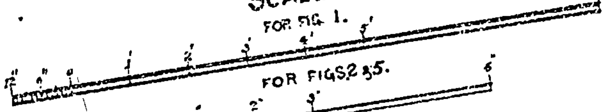


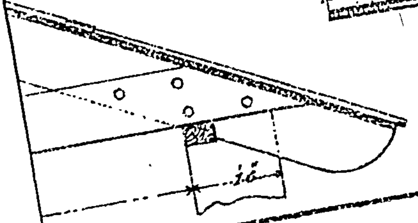
FIG. 6.
SHEET CLIP A AS FIXED BEFORE LAYING SHEETS.



SCALES.



1" Planking 6" broad.



Litho., November, 1905 — No.-1022—500.